INTERIM TECHNICAL MEMORANDUM NO. 2
Toxicity Reference Value Derivation for the Baseline Ecological Risk Assessment
Rolling Knolls Landfill, Chatham, New Jersey

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ACRONYMS AND ABBREVIATIONS

BBP	Butyl benzyl phthalate
BERA	Baseline Ecological Risk Assessment
BEHP	bis(2-ethylhexyl)phthalate
COPECs	Chemicals of Potential Ecological Concern
EcoSSL	Ecological Soil Screening Levels
ECOTOX	ECOTOXicology knowledgebase (EPA on-line database)
ERAGS	Ecological Risk Assessment Guidance for Superfund
LOAEL	Lowest observed adverse effect level
NOAEL	No observed adverse effect level
ORNL	Oak Ridge National Laboratory
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PCDD/Fs	Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzo-p-Furans
PEL	Probable Effects Level
PPM	Parts per million
RAIS	Risk Assessment Information System (on-line database)
SIM	Selective Ion Mode
SVOC	Semivolatile Organic Compound
TAL	Target Analyte List
TEL	Threshold Effects Level
TOC	Total Organic Carbon
TRV	Toxicity Reference Values
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine

EXECUTIVE SUMMARY

Interim Technical Memorandum No. 2 (ITM #2) has been prepared by Integral Consulting Inc. (Integral) to support the Baseline Ecological Risk Assessment (BERA) that will be prepared for the Rolling Knolls Landfill Superfund Site, in Chatham Township, New Jersey, on behalf of Chevron Environmental Management Company for itself and on behalf of Kewanee Industries, Inc. Alcatel-Lucent USA Inc. and Novartis Pharmaceuticals Corporation (collectively, the RKLFG).

ITM #2 presents the derivation of the toxicity reference values (TRVs) that will be used to assess potential food-chain risks and tissue concentration risks in the BERA. It was prepared in advance of the submission of the BERA to expedite the review of the TRVs and to ensure the completion of the BERA Report by early Fall 2016. The final version of ITM #2 will be submitted as an appendix to the BERA Report.

1 INTRODUCTION

Integral Consulting Inc. (Integral) has prepared Interim Technical Memorandum No. 2 (ITM #2) to support the Baseline Ecological Risk Assessment (BERA) that will be prepared for the Rolling Knolls Landfill Superfund Site, in Chatham Township, New Jersey, on behalf of Chevron Environmental Management Company for itself and on behalf of Kewanee Industries, Inc., Lucent Technologies Inc. (now Alcatel-Lucent USA Inc.) and Novartis Pharmaceuticals Corporation (collectively, the RKLFG).

ITM #2 presents the derivation of the toxicity reference values (TRVs) that will be used to assess potential food-chain risks and tissue concentration risks in the BERA. It was prepared in advance of the submission of the BERA Report to expedite the review of the TRVs and to ensure the completion of the BERA Report by early Fall 2016. The final version of ITM #2 will be submitted as an appendix to the BERA Report.

The derivation of TRVs focused on the most ecologically relevant endpoints for the protection of populations: survival, reproduction, and growth. TRVs were developed for no observable adverse effect levels (NOAELs) and lowest observable adverse effect levels (LOAELs) from standard data sources, if sufficient data was available. To the extent possible, receptor-specific TRVs were developed.

1.1 FOOD CHAIN EXPOSURE TRV DERIVATION METHODOLOGY

This section provides a summary of the TRV derivation methods for food-chain exposures.

1.1.1 Data Sources for Food Chain-Based TRVs

The principal data sources for the mammalian TRVs were the EcoSSL documents, Sample et al. (1996), and USEPA's on-line ECOTOX database[1]. Additional data sources were evaluated as needed.

There were several sources of information used for developing dose-based TRVs (i.e., those with units of mg/kg_{bw}-day). These included literature sources (e.g., Schafer et al., 1983), agency data sources, such as the *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (USEPA 1999) and the Ecological Soil Screening Level (EcoSSL) documents (e.g., USEPA, 2005a), related data sources, such as compilations prepared by Oak Ridge National Laboratory (ORNL; Sample et al., 1996), and other sources. For the avian and mammalian TRVs, precedence was given to NOAELs and LOAELs generated to support the EcoSSLs. The USEPA EcoSSL documents include a detailed compilation of NOAELs and

[1] The ECOTOX database can be accessed using this URL: http://cfpub.epa.gov/ecotox/

LOAELs for some of the organics and many of the metals identified as COPECs for this project for both mammalian and avian receptors. The NOAELs and LOAELs were handled slightly differently depending on whether avian or mammalian receptors were evaluated:

- For avian species, when multiple NOAELs or LOAELs were reported for growth, reproductive effects, or survival, the geometric mean of these values was used as the TRV, consistent with the approach used to derive the EcoSSLs.

- For mammalian species, when multiple NOAELs or LOAELs reported for growth, reproductive effects, or survival, for a single species group (e.g., mink) were available, then the geometric mean of these values was used as the TRV. This was done to allow body weight scaling to the receptors of interest.

The geometric mean is a common metric of central tendency for distributions of NOAELs and LOAELs because it is less sensitive to extreme values than the arithmetic mean. Mathematically, the geometric mean (GM) is equivalent to the n^{th} root of the product of the n TRVs, as shown in the equation below:

$$GM = [(TRV1 \times TRV2 \times \cdots \times TRVn)]^{(1/n)}$$

Alternative approaches to calculating TRVs from multiple datasets, such as the threshold effect levels (TEL) and probable effect levels (PEL) methods originally developed for deriving sediment benchmarks (CCME 1995 and MacDonald et al. 1996) will be evaluated in the BERA uncertainty assessment for select COPECs.

1.1.2 Body Weight Scaling

For avian receptors, no adjustment for body weight differences between the test organism and receptor was used. Sample et al. (1996) reported that the scaling factors for chemicals evaluated in avian studies available at that time were close to a value of one.

Receptor-specific TRVs will be used for the mammalian receptors although toxicological data for all of the specific receptors that will be evaluated in the BERA are limited. To address this, body weight scaling of the receptors relative to a common test organism (mouse or rats) was used to calculate the appropriate TRVs for the evaluated receptors using the following equation (Sample et al., 1996; Farrell-Gray and Gotelli, 2005):

$$NOAEL_{rec} = NOAEL_t \times \left(\frac{BW_t}{BW_{rec}}\right)^{0.25}$$

where,

$NOAEL_{rec}$ = NOAEL for the receptor

$NOAEL_t$	=	NOAEL for the test organism
BW_t	=	Body weight of test organism
BW_{rec}	=	Body weight of receptor

The NOAEL terms in the equation above are replaced with the LOAELs when the latter are adjusted for body weight scaling. To the extent possible, receptor-specific studies were used to derive the TRVs (e.g., the mink TRVs were based on toxicity studies using mink).

The body weights of the mouse and rat (the two common test organisms) used for body weight scaling were 25 g and 250 g, respectively. These are the default body weights recommended from USEPA (1988). Body weight scaling was not performed when the test organism dataset represented a mixture of small mammals (e.g., guinea pigs and mice). Instead, the calculated TRVs from the mouse or the mixture of small mammals will be used as the TRVs for the short-tailed shrew and meadow vole, because their body weights (15 and 39.5 g respectively)[2] were similar to those for the mouse. Body weight-scaling will be used to derive TRVs for the little brown bat because of their smaller body weight (7.5 g) relative to the mouse.

1.1.3 Extrapolating Between TRV_{NOAEL} and TRV_{LOAEL} Values

When supported by the evaluated studies, both TRV_{NOAEL}s and TRV_{LOAEL}s were derived. For some of COPECs, it may not be possible to develop both TRV_{NOAEL} and TRV_{LOAEL} values if appropriate NOAEL and LOAEL values are not available. In such cases, the following approaches were used:

1. If bounded NOAEL and LOAEL values are available for similar receptors (e.g., available for rats but not small mammals) the ratio of the bounded TRV_{LOAEL} to TRV_{NOAEL} is used to convert the original receptor TRV.

   For example, if a TRV_{NOAEL} of 1.2 mg/kg_{bw}-day is calculated for small mammals and LOAEL data are not available, but a bounded TRV_{NOAEL} and TRV_{LOAEL} of (say) 4.2 and 14.2 mg/kg_{bw}-day (respectively) are available for rats, their ratio (14.2/4.2 = 3.38) is applied to the small mammal TRV_{NOAEL} to estimate the corresponding small mammal TRV_{LOAEL} (4.1 mg/kg_{bw}-day, for this example).

2. If bounded data are not available, then

[2] The body weights for the short-tailed shrew, meadow vole, and little brown bat are from the BERA Work Plan (Integral 2016).

i) If only a TRV_{LOAEL} could be derived from the study, then the TRV_{NOAEL} was calculated by multiplying the TRV_{LOAEL} by 0.1.

ii) If only a TRV_{NOAEL} could be derived from the study, then the TRV_{LOAEL} was calculated by multiplying the TRV_{NOAEL} by 10.

Approach #2 approach is consistent with that used by Sample et al. (1996) and others.

1.2 FISH TISSUE-BASED TRVS

This section provides a summary of the TRV derivation method for fish tissue-based TRVs, which have units of mg/kg_{ww}. The fish tissue-based TRV_{NOAEL} and TRV_{LOAEL} were developed predominantly from data compiled by USACE in their Environmental Residue-Effects Database (ERED)[3]. Other data sources that were considered include the MS-Access databases from USEPA Mid-Continent Ecology Division Laboratory [based on Jarvinen and Ankley (1999)[4] and the PCB Residue Effects (PCBRes) database[5]], NYSDEC documents (e.g., Newell et al. 1987), and literature studies. The tissue-based TRVs allow direct comparison to the tissue analytical results.

Analogous to the approach use for the food-chain TRV derivation methods, both NOAEL and LOAEL tissue based TRVs will be derived (to the extent possible). The geometric mean values from multiple studies will be calculated both (1) across all of the data and (2) using the bounded NOAEL and LOAEL studies. Preference will be made for the bounded TRV_{NOAEL} and TRV_{LOAEL} values for the BERA.

Table 1-1a and **Table 1-1b** summarize the TRV_{NOAEL} and TRV_{LOAEL} values by COPEC for the mammalian and avian receptors, respectively, and **Table 1-1c** summarizes the fish tissue TRVs. The remaining sections of this document present the derivations of these TRVs. For those COPEC TRVs that are based on the EcoSSL documents are briefly discussed with supporting calculations provided in attachments. More detailed discussions are provided for those chemicals that are not included in the EcoSSL collection.

[3] The URL for ERED is the following: http://el.erdc.usace.army.mil/ered/
[4] The URL for this database is the following: http://www.epa.gov/med/Prods_Pubs/tox_residue.htm
[5] The URL for the PCBRes database is the following: http://www.epa.gov/med/Prods_Pubs/pcbres.htm

2 MAMMALIAN TRVS

The mammalian species that will be evaluated in the BERA include the following: short-tailed shrews, meadow voles, little brown bat, red fox and mink. **Table 2-1a** compiles the literature sources used to derive the mammalian TRVs for small mammals and **Table 2-1b** compiles the same for the rat. **Table 2-2a** summarizes the larger mammal (red fox and mink) TRVs after body weight scaling from the test organism and **Table 2-2b** summarizes the small mammal TRVs after body weight scaling from the test organism[6]. If toxicity information was available for a receptor of interest (e.g., mink) this was used for deriving the receptor-specific TRVs. The derivation of mammalian TRVs for the COPECs that will be evaluated in the BERA is discussed below.

2.1 MAMMALIAN TRVS FOR PHTHALATES

Two phthalate compounds [bis(2-ethylhexyl) phthalate (BEHP) and butylbenzylphthalate (BBP)] were retained as COPECs for the BERA, based on comparisons to sediment or surface water benchmarks. The recommended mammalian TRVs for these two phthalates are presented below.

2.1.1 BEHP Mammalian TRVs

Lamb et al. (1987) exposed mice to a control diet or three test diets containing 0.01%, 0.1% or 0.3% BEHP (equivalent to 10, 100 and 1,000 mg/kg, respectively) for 105 days. There was a statistically significant decrease in litters per pair, live pups per litter and pups born alive relative to control at the two higher doses but not at the lowest test dose. Sample et al. (1996) assumed a body weight of 30 g and food consumption rate of 0.0055 kg/day to derive NOAEL and LOAEL values of 18.3 and 183 mg/kg$_{bw}$-day, respectively.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat. These were body weight scaled to derive TRVs for the larger mammals (**Table 2-2a**). A review of the literature showed no NOAELs or LOAELs specific to mink for this COPEC.

2.1.2 BBP Mammalian TRVs

No relevant data were available for small mammals. Tyl et al. (2004) evaluated the toxicity of butyl benzyl phthalate (BBP) across multiple generations in rats. Rats (both sexes) were administered to a control diet and diets containing BBP at 750, 3,750, and 11,250 parts per million (ppm) *ad libitum* for two offspring generations, one litter/breeding pair/generation, and

[6] For clarity, **Table 2-2b** also includes the small mammal TRVs that did not require body weight scaling.

through weaning of F2 litters. Adult F0 systemic toxicity and adult F1 systemic and were present at the maximum test dose (11,250 mg/kg, equivalent to 750 mg/kg per day). There were no effects on parents or offspring at 750 ppm (equivalent to 50 mg/kg per day). The F1 parental systemic and reproductive toxicity no observable adverse effect level (NOAEL) was 3,750 ppm. The offspring toxicity NOAEL was 3,750 ppm. The offspring toxicity NOAEL was 750 ppm, based on the presence of reduced anogenital distance in F1 and F2 males at birth at 3,750 ppm, but no effects on reproductive development, structures, or functions.

Based on this multigenerational study, the rat TRV_{NOAEL} and TRV_{LOAEL} values for BBP are 50 mg/kg_{bw}-day and 250 mg/kg_{bw}-day, respectively. These are body weight-scaled for the large mammals in **Table 2-2a** and the small mammals in **Table 2-2b**.

2.2 MAMMALIAN TRVS FOR PAHS

The EcoSSL document for polycyclic aromatic hydrocarbons (PAHs; USEPA, 2007a) was used as the primary source for toxicity data for this class of COPECs. The Eco-SSL report divided PAHs into two groups: low molecular weight PAHs (L-PAHs) and high molecular weight PAHs (H-PAHs). The COPEC naphthalene is classified as an L-PAH while the remaining COPEC PAHs are H-PAHs (ATSDR, 1995).

2.2.1 TRVs for Low-Molecular Weight PAHs

The EcoSSL dataset for L-PAHs included NOAEL and LOAEL data for three organisms (mouse, rabbit and rat). TRVs were developed for small mammals (based on the mouse) and rats (for large mammals).

- Small mammals: There were 10 NOAEL and 9 LOAEL values available for small mammals, three of which represented bounded results. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 88.7 and 245 mg/kg_{bw}-day.

- Rats: There were 11 NOAEL and 6 LOAEL values available for the rat in the EcoSSL dataset, five of which represented bounded results. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 192 and 544 mg/kg_{bw}-day, respectively.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat (**Table 2-2b**). The rat TRVs are body weight-scaled to derive TRVs for the large mammalian receptors (**Table 2-2a**). A review of the literature showed no values specific to the mink for the L-PAHs.

2.2.2 TRVs for High-Molecular Weight PAHs

The EcoSSL dataset for H-PAHs included NOAEL and LOAEL data for three test organisms (guinea pig, mouse, and rat). TRVs were developed for small mammals (combining the guinea pig and mouse datasets) and rats (for large mammals).

- Small mammals: There were 9 NOAEL and 6 LOAEL values available for small mammals, three of which represented bounded results. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 2.67 and 11.4 mg/kg_{bw}-day.

- Rats: There were 8 NOAEL and 9 LOAEL values available for the rat in the EcoSSL dataset, eight of which represented bounded results. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 17.2 and 44.8 mg/kg_{bw}-day, respectively.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat (**Table 2-2b**). The rat TRVs are body weight-scaled to derive TRVs for the large mammalian receptors (**Table 2-2a**). A review of the literature showed no NOAELs or LOAELs specific to the mink for the H-PAHs.

2.3 MAMMALIAN TRVS FOR PENTACHLORPHENOL

The EcoSSL document for pentachlorophenol (USEPA, 2007b) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data for four species (mink, mouse, rat and sheep). TRVs were developed for small mammals (based on the mouse), rats (for large mammals other than mink), and mink.

- Small mammals: There were 6 NOAEL and no LOAEL values available for small mammals, none of which represented bounded results. The geometric mean of the TRV_{NOAEL} values is 61.4 mg/kg_{bw}-day. A TRV_{LOAEL} was estimated by multiplying this value by the ratio of the bounded TRV_{NOAEL} and TRV_{LOAEL} values for the rat (22.0/5.45 = 4.03) which yielded an estimated TRV_{LOAEL} for small mammals of 247 mg/kg-day.

- Rats: There were 21 NOAEL and 22 LOAEL values available for the rat in the EcoSSL dataset, 13 of which represented bounded results. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 5.45 and 22.0 mg/kg_{bw}-day, respectively.

- Mink: The EcoSSL dataset included results from one study that evaluated pentachlorophenol toxicity in mink. Beard and Rawlings (1998) exposed mink to a control diet or diet containing pentachlorophenol at a rate of 1 mg/kg-day across three generations (162 days). There were no effects on reproduction or survival for any of the exposed generations at this dose rate. This was converted in the EcoSSL dataset by assuming an ingestion rate of 0.0449 kg/day and body weight of 0.596 kg, yielding a TRV_{NOAEL} of 0.0753 mg/kg_{bw}-day.

However, a prior companion single generation study by Beard et al. (1997) used a similar dosing design but reported the dietary dose unit as mg/kg_{bw}-day. This study was not evaluated in the EcoSSL dataset but showed TRV_{NOAEL} for survival of 1 mg/kg_{bw}-day and TRV_{LOAEL} for reproductive effects (decreased whelping rate) of 1 mg/kg_{bw}-day. The authors were not confident whether the reproductive outcome from this single generation study was the result from a direct effect on embryo survival or an indirect behavioral effect from the absence of a second mating. Given the similarity of dosing design between the two Beard and co-worker studies it is appears that the adjustments for ingestion rate and body weight performed in the EcoSSL document for the Beard and Rawlings (1998) study were not required. Therefore, the survival and reproduction outcomes from three generation study by Beard and Rawlings (1998) will be used for the BERA, but the TRV_{NOAEL} value is corrected to 1 mg/kg_{bw}-day.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat (**Table 2-2b**). The rat TRVs are body weight-scaled to derive TRVs for the large mammalian receptors (**Table 2-2a**), except for mink.

2.4 MAMMALIAN TRVS FOR PESTICIDES

There were 20 pesticides retained for further evaluation in the BERA. These fall into seven groups that representative different isomers (e.g., DDx compounds) or represented structurally similar compounds (e.g., endrin, endrin aldehyde and endrin ketone). The studies included in the TRV derivation are summarized below.

2.4.1 Mammalian TRVs for DDD, DDE, DDT and total DDx

The EcoSSL document for DDT and metabolites (USEPA, 2007c) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included data for DDD, DDE and DDT. These are combined to ensure the availability of sufficient data to develop TRVs. The EcoSSL dataset included NOAEL and LOAEL data for a large number of mammalian species, including dog, two mice species, two bat species, hamster, rabbit, rat and sheep. TRVs were developed for small mammals (which combines the mice, bat and hamster data), rats, and bats.

- Small mammals: There were 22 NOAEL and 11 LOAEL values available for small mammals. These included four bounded NOAEL and LOAEL values. The geometric means of the TRV_{NOAEL} and TRV_{LOAEL} values are 25.2 and 52.7 mg/kg_{bw}-day, respectively.

- Rats: There were 57 NOAEL and 31 LOAEL values available for the rat in the EcoSSL dataset, 17 of which represented bounded results. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 4.52 and 14.8 mg/kg_{bw}-day, respectively.

- Bats: There were two studies in the EcoSSL dataset that evaluated DDE toxicity in bat species. A TRV_{NOAEL} of 31.9 mg/kg_{bw}-day was derived from a study by Clark and Kroll (1977) using the free-tailed bat (*Tadarida brasilensis*) and TRV_{NOAEL} and TRV_{LOAEL} values of 25.4 and 81.2 mg/kg_{bw}-day) were derived from a study by Clark and Stafford, (1981) using the little brown bat (*Myotis lucifugus*). The geometric mean of the TRV_{NOAEL} values were 28.5 mg/kg_{bw}-day and the TRV_{LOAEL} value was 81.2 mg/kg_{bw}-day. These TRVs will be used to assess potential bat risks to DDT and related pesticides in the BERA.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole. The rat TRVs are body weight-scaled to derive TRVs for the large mammalian receptors (**Table 2-2a**).

The uncertainty assessment in the BERA will evaluate the impact of TRVs based on use of DDE, DDD and DDT isomers on the calculated risks.

2.4.2 Mammalian TRVs for Aldrin and Dieldrin

Aldrin and its epoxide derivative dieldrin are synthetic chlorinated cyclodiene insecticides that were used from the 1950s to the early 1970s (USEPA 2007d). Aldrin can degrade to dieldrin in the environment via photodegration or microbial activities. Given their structural similarity, and he availability of the EcoSSL document for dieldrin (USEPA, 2007d), the TRVs that will be derived for dieldrin will also be applied to aldrin.

The EcoSSL dataset for dieldrin (USEPA, 2007d) included NOAEL and LOAEL data for 11 mammalian species [antelope (blesbuk), dog, guinea pig, mice, pig, rabbit, rat, sheep, and white-tailed deer. TRVs were developed for small mammals (combining the results for the guinea pig and mice) and rats.

- Small mammals: There were 14 NOAEL and 8 LOAEL values available for small mammals. These included four bounded NOAEL and LOAEL values (guinea pig and mouse). The geometric means of the TRV_{NOAEL} and TRV_{LOAEL} values are 1.01 and 2.72 mg/kg_{bw}-day, respectively.

- Rats: There were 23 NOAEL and 18 LOAEL values available for the rat in the EcoSSL dataset, 11 of which represented bounded results. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 1.04 and 2.83 mg/kg_{bw}-day, respectively.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat (**Table 2-2b**). The rat TRVs are body weight-scaled to derive TRVs for the large mammalian receptors (**Table 2-2a)**.

2.4.3 Mammalian TRVs for *alpha*-Chlordane and *gamma*-Chlordane

USACHPPM (2005) reviewed the mammalian toxicity of chlordane. A subset of these studies use rat as test organisms and growth and reproductive endpoints that are ecologically relevant[7]. These studies included one NOAEL and two LOAELs and are summarized in **Table 2-3**.

- Small mammals: The six generation reproduction study using mice reported in Sample et al. (1996) was used to develop the small mammal TRVs. The TRV_{NOAEL} and TRV_{LOAEL} values are 4.58 and 9.16 mg/kg_{bw}-day.

- Rats: There were 2 NOAEL and 3 LOAEL values reported in Table 2-3, two of which represented bounded results. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 2.57 and 5.53 mg/kg_{bw}-day, respectively.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat (**Table 2-2b**). The rat TRVs are body weight-scaled to derive TRVs for the large mammalian receptors (**Table 2-2a)**.

2.4.4 Mammalian TRVs for *beta*-BHC, *delta*-BHC and *gamma*-BHC (Lindane)

An EcoSSL document was not available for BHC and its related compounds. Therefore, a literature review was performed.

Palmer et al. (1978) exposed rats in their diet to three dose levels of lindane (25, 50 and 100 mg/kg) for three generations. After the 30 days of exposure a male and female were paired for mating. No adverse effects on reproduction were observed at any dose level. Therefore, the maximum test concentration represented the NOAEL dose. Sample et al. (1996) converted this to a TRV_{NOAEL} of 8 mg/kg_{bw}-day assuming a daily ingestion rate of 0.028 kg/day and a body weight of 0.35 kg. A TRV_{LOAEL} could not be calculated from this study.

This TRV will be used for all mammalian species for all three isomers of BHC. The TRV_{NOAEL} is body weight-scaled to larger mammals in **Table 2-2a** and to smaller mammals in **Table 2-2b**.

[7] USACHPPM (2005) also summarized mouse toxicity studies but reported endpoints that were not ecologically relevant (e.g., immunocompetance).

2.4.5 Mammalian TRVs for Endosulfan I and Endosulfan sulfate

An EcoSSL document was not available for endosulfan and its related compounds. Therefore, a literature review was performed.

Dikshith et al. (1984) exposed rats by oral intubation to three dose levels of endosulfan (0.75, 2.5 or 5 mg/kg$_{bw}$-day for males; 0.25, 0.75, and 1.5 mg/kg$_{bw}$-day for females) for 30 days. After the 30 days of exposure a male and female were paired for mating. No adverse effects were observed at any dose level. Sample et al. (1996) assumed that the maximum test dose for the females would be an appropriate subchronic NOAEL. However, for the BERA the geometric mean of the maximum doses for the two genders (2.74 mg/kg$_{bw}$-day) would be more appropriate because a gender neutral characterization of risks will be performed. A chronic TRV$_{NOAEL}$ (2.74E-01 mg/kg$_{bw}$-day) was estimated by multiplying the subchronic NOAEL by a subchronic-chronic uncertainty factor of 0.1, consistent with the approach taken by Sample et al. (1996). A TRV$_{LOAEL}$ could not be calculated from this study.

This TRV will be used for all mammalian species for all three isomers of BHC. The TRV$_{NOAEL}$ is body weight-scaled to larger mammals in **Table 2-2a** and to smaller mammals in **Table 2-2b**.

2.4.6 Mammalian TRVs for Endrin, Endrin aldehyde and Endrin ketone

An EcoSSL document was not available for endrin and its related compounds. Therefore, a literature review was performed.

Good and Ware (1969) exposed mice to 5 mg/kg of endrin in their diet for 120 days. There was significant survival (parental) and reproductive effects (reduced litter size, and number of young per female) at the single test dose. Based on this study, Sample et al (1986) derived a TRV$_{LOAEL}$ of 0.92 mg/kg$_{bw}$-d using the food consumption rate (0.0055 kg/d) based on allometric equation and an assumed body weight (0.03 kg). The TRV$_{NOAEL}$ was assumed to be 10-fold lower (0.092 mg/kg$_{bw}$-d) by Sample et al. (1996).

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole. These are body weight-scaled for the little brown bat (**Table 2-2b** the large mammalian receptors (**Table 2-2a**).

2.4.7 Mammalian TRVs for Heptachlor and Heptachlor epoxide

TRVs for heptachlor and heptachlor epoxide were derived for mink, and mammals other than mink, based on literature values.

- Mammals other than mink: The mammalian toxicity of heptachlor has been reviewed by Kielhorn et al. (2006). Many of these exposures were by injection rather than oral exposure, but the daily dose rates can be calculated from the information provided or where reported by the original authors. The studies that used rats have been summarized in **Table 2-4**. The primary endpoints evaluated were growth (weights relative to control) or reproductive effects. The geometric mean TRV_{NOAEL} and TRV_{LOAEL} values from the two rat studies are 2.93 and 3.35 mg/kg_{bw}-day. None of these represented bounded results.

- Mink: Crum et al. (1993) exposed mink to a control diet or diet containing 6.25, 12.5 or 25 mg/kg of heptachlor for 181 days. The daily doses reported by the authors for the three test doses were 1.0, 1.7, and 3.1 mg/kg_{bw}-day. Adverse effects on reproduction (reduced fertility, reduced kit survival, reduced kit weight) were observed at all test doses. Therefore the minimum test dose (1.0E+00 mg/kg_{bw}-day) represents the TRV_{LOAEL}. Sample et al. (1996) assumed that the TRV_{NOAEL} was one-tenth this value (1.0E-01 mg/kg_{bw}-day). These are the same TRV_{NOAEL} and TRV_{LOAEL} that were used in the BERA Work Plan (Integral 2016) to assess mink.

The TRVs calculated from the rat data will be body weight-scaled for all of the mammalian receptors, except for the mink.

2.5 MAMMALIAN TRVS FOR TOTAL PCBS

TRVs for Total PCBs were derived for mink, and mammals other than mink, based on literature values. TRVs were developed using Aroclor 1254 (as it was the predominant form of PCBs reported in the Site soil or sediment) or "environmental PCBs" that might be representative of the exposure pathways that could occur at the Site.

2.5.1 PCB TRVs for Mink

Basu et al. (2007) and Fuchsman et al. (2008) have reviewed the PCB toxicity studies using mink. The key studies have been compiled in **Table 2-5** and are briefly summarized below.

Platanow and Karstad (1973) fed mink diets containing beef from cattle that had been exposed to Aroclor 1254 in their diets. The dietary total PCB concentrations were 0.64 and 3.57 ppm. The samples also included low levels of pesticides. Mink were fed *ad libitum* for 105 days, overlapping the breeding period and period prior to whelping of the kits. There was a slight decrease in survival at the lower dose, and this dose level also reduced reproduction. Based on these results, the lower dose level (0.64 ppm) would be considered a LOAEL. Body weights and food ingestion rates were not provided by the authors. Assuming a body weight of 1 kg (USEPA, 1993) and ingestion rate of 0.137 kg/day (Sample et al., 1996), the calculated TRV_{LOAEL} was 0.088 mg/kg_{bw}-day.

Aulerich and Ringer (1977) fed mink Aroclor 1254 at three dietary dose levels (1, 5 and 15 ppm) over a 4.5 month period. Aroclor 1254 at 5 and 15 ppm in the diet reduced the number of offspring that were born alive. Based on this information, Sample et al. (1996) considered the 5 ppm dose to represent a chronic LOAEL and the 1 ppm dose was considered to be a chronic NOAEL. Based on the average body weights and ingestion rates, this yielded a TRV_{NOAEL} and TRV_{LOAEL} of 0.137 and 0.685 mg/kg-day, respectively.

Aulerich et al. (1985) fed mink Aroclor 1254 to a single dietary dose (2.5 ppm) over a 102 period. This included the one month prior to breeding through parturition. At this dose level there was a reduction in reproductive success relative to control. Based on this information, the 2.5 ppm represents a LOAEL. Using the average body weights and ingestion rates reported by the authors, this yielded a TRV_{LOAEL} of 0.307 mg/kg-day.

Hornshaw et al. (1986) exposed male and female adult and young mink to Aroclor 1254 for a 28-day exposure period and monitored survival and growth rates. This was performed as part of an LC_{50} study. Five dietary dose levels were used (10, 18, 32.4, 58.3, and 105 ppm). Three separate tests were performed, which varied in the age of the tested mink and dietary formulations. In the first two tests, mortality was observed at dietary levels of 32.4 ppm or higher. In the third test, which consisted of mink older than 13 months, mortality was observed at the 23.1 ppm dose (there was also some mortality at 7.1 ppm but not at 12.9 ppm, suggesting the former results may be an anomalous result). The LC_{50} values for diet ranged from 79 to 84 ppm for the 28-day test. Although TRVs were calculated from this study it was not included in the overall TRV calculations for this species because the testing period did not represent a chronic exposure.

Wren et al. (1987) exposed adult male and female mink to a diet containing 1 ppm of Aroclor 1254 for 185 days and monitored adult survival, and kit survival and growth. There was no statistically significant impact on kit production or mortality, but there was a statistically significant decrease in body weights of kits at three or six weeks of age. Therefore, the dietary concentration of 1 ppm represents a LOAEL for this study. Based on this information, Fuchsman et al. (2008) calculated a TRV_{LOAEL} of 0.18 mg/kg-day.

Tillitt et al. (1996) fed female mink diets containing Saginaw River (Michigan) carp to yield dietary total PCB concentrations of 0.72, 1.53 and 2.56 ppm. The fish tissues also included PCDD/Fs, which represented on average 56% of the combined PCB and PCDD/F toxic equivalency. Mink were fed *ad libitum* for 182 days, overlapping the breeding period and period prior to whelping of the kits. There were no statistically significant differences in the gestation period, although at the upper dose there was a significant decline in the number of live kits that were whelped. There was also a statistically significant decline in kit survival and body weights after 3 weeks from material exposure to 0.72 ppm in the diet. The authors concluded that the lowest dose represented a LOAEL and the control (which contained 0.015 ppm of total PCBs) represented the NOAEL. Body weights and food ingestion rates were not provided by the authors. Assuming a body weight of 1 kg (USEPA, 1993) and ingestion rate of

0.137 kg/day (Sample et al., 1996), the calculated TRV_{NOAEL} and TRV_{LOAEL} are 0.002 and 0.099 mg/kg-d, respectively.

Brunström et al. (2001) exposed female mink to a technical grade of PCBs (Clophen A50, similar to Aroclor 1254) at two dose levels (0.1 or 0.3 mg/animal-day) for 18 months. Maternal growth, reproductive success and litter survival were monitored. There was a slight decrease in average maternal body weight at the higher PCB dose after 18 months but this was not statistically significant. Litter sizes were comparable between the two PCB doses and controls, although average birth weight was statistically significantly lower at the higher dose. Based on these results, the lower dose represents a NOAEL. Using the reported average body weights (range of 1.13 to 1.50 kg; mean of 1.23 kg), this yields a TRV_{NOAEL} of 0.081 mg/kg-day. The upper dose range can be considered a LOAEL, which yields a calculated TRV_{LOAEL} of 0.24 mg/kg-day.

Bursian et al. (2003) fed female mink diets that included fish from the Housatonic River in Massachusetts. The total dietary PCB concentrations were 0.34, 0.61, 0.96, 1.6, and 3.7 ppm. Mink were exposed for a total of 160 days overlapping the breeding period and period prior to whelping of the kits. Trace levels of pesticides (below levels reported toxic to mink) were also detected in the fish samples. Adult growth rates and survival, and kit survival were monitored. There were no statistically significant effects on adult growth, survival, or gestation periods, at any of the dietary doses. There was a statistically significant increase (relative to control) in kit body weights after three weeks at the 0.61 ppm maternal dietary concentration, and statistically significant decrease (relative to control) at the maximum dose (3.7 ppm). However, the kit body weights after six weeks at the maximum dose were not statistically significantly different relative to control. Based on this information, the maximum dose represents a LOAEL, while the preceding dose level (1.6 ppm) represents the NOAEL. The authors reported the daily doses at each exposure level, which were 0.169 and 0.414 mg/kg_{bw}-day, and these were used for the TRV_{NOAEL} and TRV_{LOAEL}, respectively.

Bursian et al. (2006a) fed female mink diets that contained carp collected from the Saginaw River (Michigan). The total dietary PCB concentrations were 0.03, 0.83, 1.1, and 1.7 ppm. Trace levels of PCDD/Fs were also detected in the diets. Mink were exposed for three weeks prior to breeding through weaning of kits. Mink kits were maintained on the same diets as their mothers for 27 weeks. Consumption of diets containing Saginaw River carp had no effect on breeding success, whelping success gestation length, litter size, or kit survival. Mandibular lesions were reported in some of the mink kits that were exposed *in utero* and following weaning to diets containing 20% carp (equivalent to 1.1 ppm of total PCBs in the feed), but the ecological relevance of this lesion is unclear. Based on these results, the maximum dose (1.7 ppm) represented the NOAEL. Assuming a body weight of 1 kg (USEPA, 1993) and ingestion rate of 0.137 kg/day (Sample et al., 1996), this corresponds to a TRV_{NOAEL} of 0.233 mg/kg_{bw}-day.

The geometric means of the mink TRV_{NOAEL}s and TRV_{LOAEL}s from these eight studies [the values from Hornshaw et al. (1986b) were excluded, as noted above] were 0.062 and 0.229 mg/kg_{bw}-day

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(respectively). These values will be used for the BERA risk calculations for assessing PCB exposures to mink.

2.5.2 PCB TRVs for Mammals Other than Mink

Review of the ECOTOX database showed that there was a greater frequency of toxicity data reported for mice than rats, so the TRV review for PCBs focused on mice. The key studies have been compiled in **Table 2-6** and are briefly summarized below.

Linzey (1987) evaluated reproductive success in wild caught and laboratory-reared white-footed mice (*Peromyscus leucopus*) exposed to 10 ppm of Aroclor 1254 in their diets. There was a statistically significant reduction in the number of surviving offspring per litter in the PCB exposed mice wild caught, but no effect on other reproductive parameters (e.g., litter size at birth). Based on this information, the 10 ppm dose level represents a LOAEL. Using the average body weights (23.2 g) and average food consumption rate (0.127 g/g_{bw}-d) reported by the author, the calculated TRV_{LOAEL} was 1.27 mg/kg_{bw}-day.

Linzey (1988) evaluated the survival and growth of the second generation of mice from Linzey (1987) study. At the same dose level of 10 ppm of Aroclor 1254, the second generation offspring PCBs-treated second generation mice exhibited poor reproductive success relative to controls, and grew at a slower rate compared to controls. The same TRV_{LOAEL} calculated from Linzey (1987) is applicable to this current study.

Simmons and McKee (1992) fed white-footed mice (*P. leucopus*) diets containing Aroclor 1254 at four dietary levels (2.5, 25, 50, and 100 ppm) for 21 days and monitored survival. There was no effect of PCB exposure at the 2.5 ppm diet concentration and a slight effect at 25 ppm. The latter represents the LOAEL and the 2.5 ppm level a NOAEL. Based on the average body weight and ingestion rate, this yields TRV_{NOAEL} and TRV_{LOAEL} values of 0.36 and 3.6 mg/kg_{bw}-d, respectively. The TRV_{NOAEL} corresponds to the "TRV-low" recommended by USEPA Region 9 (USEPA 2002).

McCoy et al. (1995) exposed three generations of oldfield mice (*Permyscus polionotus*) to a diet containing 5 ppm of Aroclor 1254 for 12 months and monitored reproduction. Dietary exposure reduced the number of litters, offspring weights, and offspring survival. Sample et al. (1996) concluded that this dietary level represented a LOAEL, and based on literature values for body weights and ingestion rates (this information was not provided by the authors), derived a TRV_{LOAEL} of 0.68 mg/kg_{bw}-day.

Voltura and French (2007) fed breeding female white-footed mice (*P. leucopus*) for four months on diets containing a mixture of Aroclors 1242 and 1254 (ratio of 2:1) at dietary levels of 10 and 25 ppm and monitored reproductive success. There was no effect of PCB exposure on litter size at birth or weaning, although there was a statistically significant reduction in reproductive success in female mice that were fed the 25 ppm diet. Based on this information, the latter represents the LOAEL and the 10 ppm level a NOAEL. The authors calculated daily ingestion rates of 2.64 mg/kg_{bw}-day for the 10 ppm diet and 6.19 mg/kg_{bw}-day for the 25 ppm diet, which represents the TRV_{NOAEL} and TRV_{LOAEL}, respectively.

The geometric means of the mouse TRV_{NOAEL}s and TRV_{LOAEL}s from these studies were 0.975 and 1.90 mg/kg_{bw}-day (respectively). The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat (**Table 2-2b**). The rat TRVs are body weight-scaled to scaled to derive values for the larger mammalian receptors other than mink (**Table 2-2a**).

2.6 MAMMALIAN TRVS FOR PCDD/F-TEQ AND PCB-TEQ

TRVs for PCDD/F-TEQ and PCB-TEQ were based on toxicity studies using "environmental TEQs" or 2,3,7,8-TCDD in the published literature. **Table 2-7** summarizes the data for mink and **Table 2-8** summarizes the toxicity data for rats that are body weight scaled for the mammalian receptors other than mink. For all data summaries the original reporting units for dose or exposure are presented but these are converted to mg/kg_{bw}-day for the TRVs.

2.6.1 TCDD TRVs for Mink

Blankenship et al. (2008) performed a synoptic review of the Dioxin-TEQ toxicity to mink. From a collection of 32 publications, they recommended four key studies (Bursian et al. 2006a, Bursian et al. 2006b, Heaton et al. 1995, and Zwiernik et al. 2009) that can be used to develop dietary NOAEL and LOAEL concentrations (units of ng/kg_{ww} feed) for PCDD/F-TEQ and PCB-TEQ. Three of these studies were based on exposure to "environmental TEQs" using feed containing fish collected from the Housatonic River (MA), Saginaw River (MI) and Saginaw Bay (MI). The dietary NOAEL and LOAEL concentrations are shown in **Table 2-7** and are converted to mg/kg_{bw}-day by assuming a food ingestion rate of 0.137 kg_{ww}/day (Bleavins and Aulerich 1981) and body weight of 1 kg (USEPA 1993)[8]. The geometric means of the TRV_{NOAEL} and TRV_{LOAEL} values across all four studies are 3.58E-06 and 8.08E-06 mg/kg_{bw}-day, respectively. There were two studies (Bursian et al.2006b and Zwiernick et al.2009) that had bounded NOAEL and LOAEL values. The geometric means of the TRV_{NOAEL} and TRV_{LOAEL} values from the two bounded studies are 2.43E-06 and 1.51E-05 mg/kg_{bw}-day, respectively. Although using bounded study results is preferred to derive TRVs, the TRVs generated from all four studies will be used in this case because it is based on additional environmental TEQ data.

[8] The food ingestion rate and body weight values are the same as those used in the BERA Work Plan (Integral 2016).

2.6.2 TCDD TRVs for Mammals other than Mink

Toxicological studies that have assessed the effects of TCDD on growth, reproduction and survival endpoints on species other than mink are limited (USEPA 2012). Studies using rats are summarized in **Table 2-8**.

Kociba et al. (1976) evaluated the subchronic toxicity of 2378-TCDD in Sprague-Dawley rats. Rats were exposed by oral gavage (corn oil base) to control and four doses (0.001, 0.01, 0.1 and 1 $\mu g/kg_{bw}$) five days per week to 2378-TCDD for a total of 13 weeks (subchronic exposure). The calculated average daily doses were 0 (control), 0.71, 7.14, 71.4, and 714 ng/kg_{bw}-day. Reduced body weights relative to control were observed in the 71.4 ng/kg_{bw}-day dose group, which is equivalent to a TRV_{LOAEL} of 7.14E-05 mg/kg-day. The TRV_{NOAEL} is the next lowest dose (7.1E-06 mg/kg-day). This study was reported in the EPA Ecotox database.

In a companion study, Kociba et al. (1978) exposed rats for two years by oral gavage to control and three doses (0.001, 0.01, 0.1 $\mu g/kg_{bw}$-day). Ingestion of the maximum dose resulted in increased mortality, decreased weight gain, increased incidence of tumors, and affected multiple biochemical parameters, relative to control rats. Ingestion of 0.001 $\mu g/kg_{bw}$-day (which corresponded to approximate diet concentration of 22 ng/kg) caused no effects considered to be of any toxicological significance. This dose (equivalent to 1.0E-06 mg/kg-day) represents the TRV_{NOAEL}. The next highest dose (0.01 $\mu g/kg_{bw}$-day; equivalent to 1.0E-05 mg/kg-day) represents the TRV_{LOAEL}.

Murray et al. (1979) reported the results of a rat feeding study using 2,3,7,8-TCDD across three generations. The measurement endpoint was reproductive success. The dietary 2,3,7,8-TCDD doses were 0.001, 0.01 and 0.1 $\mu g/kg_{bw}$-day. Fertility and neonatal survival was significantly reduced among rats receiving 0.1 and 0.01 $\mu g/kg_{bw}$-day. Because no significant differences were observed at the 0.001 $\mu g/kg_{bw}$-day dose level (equivalent to 1.0E-06 mg/kg-day) this dose was considered to be a chronic NOAEL. The 0.01 $\mu g/kg_{bw}$-day dose (equivalent to 1.0E-05 mg/kg-day) was considered to be a chronic LOAEL. This is the study and toxicity benchmarks reported by Sample et al. (1996) and also recommended by USEPA (1999) for mammals.

Croutch et al. (2005) reported the results of a rat feeding study using 2,3,7,8-TCDD across a 128-day exposure period. Rats were exposed by oral gavage (corn oil base) to 0, 0.0125, 0.05, 0.2, 0.8, or 3.2 $\mu g/kg_{bw}$ at time zero followed by a "maintenance dose" dose rates about one tenth of the loading dose every 3 days. The "maintenance dose" was based on the half-life of TCDD in rats (approximately 20 days) with the intent to maintain steady-state concentrations in the rats. These convert to average daily 2,3,7,8-TCDD doses of 0, 0.85, 3.4, 13.6, 54.3 and 217 ng/kg_{bw}-day (as reported in USEPA 2012). Statistically significant decrease in body weights were observed rats relative to control in the maximum dosed group, which represents the TRV_{LOAEL} (2.17E-04 mg/kg_{bw}-day). The next lowest dose (5.43E-05 mg/kg_{bw}-day) represents the TRV_{NOAEL}.

Walker et al. (2006) reported the results of the National Toxicology Program study of TCDD chronic toxicity and carcinogenicity, which included information on mortality and growth effects. Female Sprague Dawley rats were exposed by oral gavage to control and five doses (3, 10, 22, 46 and 100 ng/kg_{bw}) five days per week to 2,3,7,8-TCDD for a total of two years. The calculated average daily doses reported by the authors were 0, 2.1, 7.1, 15.7, 32.9 and 71.4 ng/kg_{bw}-day. There were no impacts on cumulative survival across the study test doses but there was decreased body weights relative to control in rats exposed to the three highest doses. The incidence of neoplastic lesions were comparable to the controls at the two lower doses (3 and 10 ng/kg_{bw}). Based on these results, an unbounded TRV_{NOAEL} for survival was the maximum test dose (7.14E-05 mg/kg_{bw}-day), and bounded TRV_{NOAEL} and TRV_{LOAEL} values for growth (body weight gain) of 7.1E-06 and 1.57 E-05 mg/kg_{bw}-day (respectively) were derived.

Synopsis

The geometric mean TRV_{NOAEL} and TRV_{LOAEL} values across all of these rat studies are 7.62E-06 and 3.00E-05 mg/kg_{bw}-day, respectively. The geometric mean TRV_{NOAEL} and TRV_{LOAEL} values across the five bounded study results are 4.87E-06 and 3.00E-05 mg/kg_{bw}-day, respectively. The bounded TRVs are recommended for use in the BERA. These TRVs have been body weight scaled to small mammals and large mammals other than mink in **Table 2-2b** and **Table 2-2a** (respectively).

2.7 MAMMALIAN TRVS FOR METALS AND CYANIDE

The mammalian TRVs for metals were derived predominantly from toxicity data summarized in the EcoSSL documents. These were supplemented where appropriate with other studies reported in the literature. Receptor-specific TRVs are also discussed below for each COPEC.

2.7.1 Antimony Mammalian TRVs

The EcoSSL document for arsenic (USEPA, 2005a) was used as the primary source for toxicity data. The EcoSSL dataset included NOAEL and LOAEL data for rats, mice, and voles. The data for the mouse and voles were combined to derive the TRVs for the small mammal receptors. The rat studies were used to derive the TRVs for the larger mammals after body weight scaling.

- Small mammals: There were a total of 9 NOAEL and 4 LOAEL values available in the dataset, three of which were bounded results (mouse only). The geometric means of the bounded NOAEL and LOAEL values were 185 and 279 mg/kg_{bw}-day, respectively

- Rats: There were a total of 8 NOAEL and 4 LOAEL values available in the dataset, two of which were bounded results. The geometric means of the bounded NOAEL and LOAEL values were 0.6 and 5.0 mg/kg_{bw}-day, respectively.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat. The rat TRVs are body weight-scaled to assess potential risks in larger mammals.

2.7.2 Arsenic Mammalian TRVs

The EcoSSL document for arsenic (USEPA, 2005b) was used as the primary source for toxicity data. The EcoSSL dataset included NOAEL and LOAEL data for multiple organisms (dog, goat, guinea pig, mice, pig, rabbit, rat, sheep). The data for the guinea pig and mouse were combined to derive the TRVs for the small mammal receptors. The rat studies were used to derive the TRVs for the larger mammals after body weight scaling.

- Small mammals: There were a total of 7 NOAEL and 13 LOAEL values available in the dataset, four of which were bounded results (mouse only). The geometric means of the bounded NOAEL and LOAEL values were 10.1 and 25.5 mg/kg_{bw}-day, respectively.

- Rats: There were a total of 29 NOAEL and 13 LOAEL values available in the dataset, seven of which were bounded results. The geometric means of the bounded NOAEL and LOAEL values were 8.0 and 14.2 mg/kg_{bw}-day.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat. The rat TRVs are body weight-scaled to assess potential risks in larger mammals.

2.7.3 Barium Mammalian TRVs

The EcoSSL document for barium (USEPA, 2005c) was used as the primary source for toxicity data. The EcoSSL dataset included NOAEL and LOAEL data from rats and mice as test organisms. The data for the mouse were used derive the TRVs for the small mammal receptors. The rat studies were used to derive the TRVs for the larger mammals after body weight scaling.

- Small mammals: There were three NOAEL and four LOAEL results available in this dataset, three of which were bounded results (mouse only). The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values were 165 and 436 mg/kg_{bw}-day, respectively.

- Rats: There were eight NOAEL and four LOAEL results available in this dataset, four of which were bounded results. The geometric means of the four bounded TRV_{NOAEL} and TRV_{LOAEL} values were 91.7 and 155 mg/kg_{bw}-day.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat. The rat TRVs are body weight-scaled to assess potential risks in larger mammals.

2.7.4 Cadmium Mammalian TRVs

The EcoSSL document for cadmium (USEPA, 2005d) was used as the primary source for toxicity data. The EcoSSL dataset included NOAEL and LOAEL data for multiple organisms (cattle, dog, goat, mouse, pig, rabbit, rat, sheep, shrews and two species of voles). The data for the shrew, mouse and vole species were combined to derive the TRVs for the small mammal receptors. The rat studies were used to derive the TRVs for the larger mammals after body weight scaling.

- Small mammals: There were 22 NOAEL and 15 LOAEL results available in this dataset, seven of which were bounded results. The geometric means of the seven bounded TRV_{NOAEL} and TRV_{LOAEL} values were 4.21 and 28.6 mg/kg_{bw}-day, respectively. The shrew results were unbounded NOAEL or LOAEL values (depending on endpoint) from a single study. Therefore it was preferable to used TRVs from the larger group of small mammals to assess the small mammals.

- Rats: There were 64 NOAEL and 58 LOAEL results available in this dataset, 28 of which were bounded results. The geometric means of the 28 bounded TRV_{NOAEL} and TRV_{LOAEL} values were 1.7 and 9.4 mg/kg_{bw}-day.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat. The rat TRVs are body weight-scaled to assess potential risks in larger mammals.

2.7.5 Chromium Mammalian TRVs

The EcoSSL document for chromium (USEPA, 2008) was used as the primary source for toxicity data. The EcoSSL dataset for trivalent chromium included NOAEL and LOAEL data for multiple organisms (cattle, mouse, pig, and rat). The data for the small mammals (2 NOAELs and 1 LOAEL) and rat (4 NOAELs and 1 LOAEL) were very limited. Geometric mean calculations of the small mammal and rat datasets also yielded lower TRV_{LOAEL} vales than TRV_{NOAEL} values. Therefore, the geometric means across all of the test organisms are recommended for use in the BERA without body weight scaling.

- All mammals: There were a total of 10 NOAEL and 2 LOAEL values available in the dataset across all test organisms, none of which represented bounded results. The geometric means of these NOAEL and LOAEL values were 2.77 and 16.1 mg/kg_{bw}-day, respectively.

These TRVs will be used without any body weight scaling for the evaluated mammalian receptors. The use of "all mammals" to derive the chromium TRV for the small and large mammalian receptors will be evaluated in the uncertainty section of the BERA Report.

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2.7.6 Cobalt Mammalian TRVs

The EcoSSL document for cobalt (USEPA, 2005e) was used as the primary source for toxicity data. The EcoSSL dataset included NOAEL and LOAEL data for multiple organisms (cow, guinea pig, mouse, pig, and rat). The data for the guinea pig and mouse were combined to derive the TRVs for the small mammal receptors. The rat studies were used to derive the TRVs for the larger mammals after body weight scaling.

- Small mammals: There were a total of 4 NOAEL and 7 LOAEL values available in the dataset, only one of which was a bounded result (mouse only). The geometric means of the full set of NOAEL and LOAEL values were 40.0 and 26.6 mg/kg$_{bw}$-day, respectively. Given that the calculated TRV$_{LAOEL}$ was less than the TRV$_{NOAEL}$, it is recommended to use the values from the single bounded study, which were 19 and 33 mg/kg$_{bw}$-day, respectively, to assess small mammals.

- Rats: There were a total of 5 NOAEL and 7 LOAEL values available in the dataset, two of which represented bounded results. The geometric means of the full set of NOAEL and LOAEL values were 7.2 and 13.4 mg/kg$_{bw}$-day. The bounded results had similar values (5.2 and 14.8 mg/kg$_{bw}$-day) but it is recommended to use the larger dataset for the BERA.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat. The rat TRVs are body weight-scaled to assess potential risks in larger mammals.

2.7.7 Copper Mammalian TRVs

The EcoSSL document for copper (USEPA, 2007e) was used as the primary source for toxicity data. The EcoSSL dataset included NOAEL and LOAEL data for multiple organisms (cattle, common shrew, goat, guinea pig, horse, mink, mouse, pig, rabbit, rat and sheep). The data for the shrew, guinea pig and mouse were combined to derive the TRVs for the small mammal receptors. The mink studies were used to derive the mink TRVs and the rat data were used to develop the TRVs for the red fox after body weight scaling.

- Small mammals: There were 21 NOAEL and 10 LOAEL values for small mammals in the EcoSSL dataset, 10 of which represented bounded results (mouse only). The geometric means of the bounded TRV$_{NOAEL}$ and TRV$_{LOAEL}$ values were 384 and 838 mg/kg$_{bw}$-day, respectively.

  The small mammal EcoSSL dataset included NOAEL for two endpoints (growth and survival) of 229 mg/kg$_{bw}$-d for the shrew from a single study. This represents the TRV$_{NOAEL}$. The TRV$_{LOAEL}$ for the shrew was estimated to be 499 mg/kg$_{bw}$-day, by multiplying the shew TRV_{NOAEL} by the ratio of the bounded TRVs for all small mammals (838/384=2.18).

- Rats: There were 27 NOAEL and 23 LOAEL values for rats in the EcoSSL dataset, 13 of which represented bounded results. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values were 98.6 and 186 mg/kg_{bw}-day, respectively.

- Mink: There were six NOAEL and three LOAEL values for the mink, three of which represented bounded values. The geometric mean of the three bounded TRV_{NOAEL} and TRV_{LOAEL} values were 7.1 and 13.8 mg/kg_{bw}-day, respectively.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat. The mink TRVs will be used to assess potential risks to minks and the rat TRVs are body weight-scaled to assess potential risks in large mammals other than the mink.

2.7.8 Cyanide Mammalian TRVs

An EcoSSL document for cyanide was not available. Much of the literature regarding mammalian cyanide toxicity has focused on acute or subchronic exposures, reported LD_{50} results, or evaluated endpoints that were not ecologically relevant, such as biomarker results (e.g., Eisler 1991, ADHA 2010). **Table 2-9** summarizes the studies used to derive the mammalian cyanide TRV.

Tewe and Maner (1981) exposed rats to a diet containing 500 ppm of cyanide for 19 days before mating and throughout gestation and lactation. The offspring were also fed a diet at this concentration for 28 days post-weaning. There was a slight reduction in body weight gain in the offspring (less than 7% relative to control), which this was not considered to be biologically significant. Based on this study, Sample et al. (1986) derived a TRV_{NOAEL} of 68.7 mg/kg_{bw}-d using the food consumption rates and body weights reported in the Tewe and Maner (1981) study. The TRV_{LOAEL} was assumed to be 10-fold higher by Sample et al. (1986).

NTP (1993) performed a 13-week drinking water supply study using F344/N Rats and B6C3F1 Mice. Rats and mice were exposed to control water and water containing 3, 10, 30, 100 or 300 mg/L of sodium cyanide. Reproduction, growth and survival endpoints were monitored throughout the study. There were no statistically significant differences for any of these endpoints in female rats across all doses. Male rats exhibited reproductive effects at 300 mg/L, which represented the test dose LOAEL. The next lowest dose (100 mg/L) represented the NOAEL. NTP (1993) reported that the NOAEL and LOAEL doses were equivalent to 4.50 and 12.5 mg/kg_{bw}-day.

For mice, there were no statistically significant differences with any of the metrics across the all the test doses. Therefore, the maximum test dose (300 mg/L) was considered the NOAEL. NTP (1993) reported that the NOAEL dose was equivalent to 28.8 mg/kg_{bw}-day.

- Small mammals: Based on the NTP study results using mice the TRV_{NOAEL} for the small mammals is 28.8 mg/kg_{bw}-day. A TRV_{LOAEL} cannot be calculated from this study,
- Rats: Combining the results of the Tewe and Maner (1981) and NTP (1993) study results yields geometric mean TRV_{NOAEL} and TRV_{LOAEL} values of 17.6 and 92.7 mg/kg_{bw}-day.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat (**Table 2-2b**). The rat TRVs are body weight-scaled to assess potential risks in larger mammals (**Table 2-2a**).

2.7.9 Lead Mammalian TRVs

The EcoSSL document for lead (USEPA, 2005f) was used as the primary source for toxicity data. The EcoSSL dataset included NOAEL and LOAEL data for multiple organisms (cattle, cotton rat, dog, guinea pig, hamster, horse, mice, pig, rabbit, rat, sheep and shrews). The data for the guinea pig, mice and shrews were combined to derive the TRVs for the small mammal receptors. The data for the rat was used to develop the TRVs for the larger mammals (red fox and mink). These TRVs are summarized below.

- Small mammals: There were 22 NOAEL and 37 LOAEL values for small mammals in the EcoSSL dataset, nine of which represented bounded results (mouse only). The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values were 126 and 451 mg/kg_{bw}-day, respectively.
- Rats: There were 86 NOAEL and 106 LOAEL values for rats in the EcoSSL dataset, 38 of which represented bounded results. The geometric mean of the bounded TRV_{NOAEL} and TRV_{LOAEL} values were 38.2 and 113 mg/kg_{bw}-day, respectively.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat (**Table 2-2b**). The rat TRVs are body weight-scaled to assess potential risks in larger mammals (**Table 2-2a**).

2.7.10 Manganese Mammalian TRVs

The EcoSSL document for manganese (USEPA 2007f) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data for multiple organisms (cattle, hamster, mouse, pig, rabbit, rat, sheep and water buffalo). The data for the hamster and mouse were combined to derive the TRVs for the small mammal receptors.

The data for the rat was used to develop the TRVs for the larger mammals (red fox and mink). These TRVs are summarized.

- Small mammals: There were 7 NOAEL and 2 LOAEL values for small mammals in the EcoSSL dataset, none of which represented bounded results (mouse and hamster). The geometric means of these TRV_{NOAEL} and TRV_{LOAEL} values were 159 and 284 mg/kg_{bw}-day, respectively.

- Rats: There were 21 NOAEL and 10 LOAEL values for rats in the EcoSSL dataset, seven of which represented bounded results. Geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values were 94.6 and 245 mg/kg_{bw}-day, respectively.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat (**Table 2-2b**). The rat TRVs are body weight-scaled to assess potential risks in larger mammals (**Table 2-2a**).

2.7.11 Mercury Mammalian TRVs

An EcoSSL document was not available for mercury. TRVs were derived for both inorganic and organic (methyl-) mercury based review of the literature. The inorganic mercury TRV will be used to assess exposure to abiotic media (i.e., soils, sediment and surface water) and the methylmercury TRVs will be used to assess exposures via forage and prey items, based on the presumption that any mercury retained in biological tissues would predominantly be in the form of methylmercury. TRVs were developed for mink and mammals other than mink.

Inorganic Mercury TRVs for Mammals other than Mink

Revis et al. (1989) exposed adult mice for 20 months to a diet containing mercuric sulfide and monitored growth and survival. Dose levels up to 13.2 mg/kg_{bw}-d were evaluated. There was no toxicity at any of the dose levels. Based on this study, Sample et al. (1996) derived a TRV_{NOAEL} of 13.2 mg/kg_{bw}-day. A TRV_{LOAEL} could not be calculated from this study. The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat (**Table 2-2b**). The rat TRVs are body weight-scaled to assess potential risks in larger mammals other than mink (**Table 2-2a**).

Methylmercury TRVs for Mammals other than Mink

Verschuuren et al. (1976) performed a three generation study using rats exposed methyl mercury chloride. Rats were fed at three dose levels (0.1, 0.5 and 2.5 ppm methyl mercury). Adverse effects were not observed at the low or intermediate doses and there was reduced pup viability at the maximum dose. After adjustment for the relative portion of methyl mercury in the dose (85.88%), and using an ingestion rate of 0.028 kg/day (Sample et al. 1996) and body weight of 0.35 kg (Sample et al. 1996), the TRV_{NOAEL} and TRV_{LOAEL} from this study are 0.034 and

0.17 mg/kg$_{bw}$-day, respectively. These TRVs were body weight-scaled to derive TRVs for small mammals (**Table 2-2b**) and large mammals other than mink (**Table 2-2a**).

Inorganic Mercury TRVs for Mink

Aulerich et al. (1974) exposed adult mink to a diet containing 10 ppm of mercuric chloride for 6 months and monitored reproductive success. There was a slight reduction in body weight gain in the offspring (less than 9% relative to control), but fertility and kit survival were unaffected at this dietary dose level. Based on this study, Sample et al. (1996) derived a TRV$_{NOAEL}$ of 1.0 mg/kg$_{bw}$-day using the food consumption rates and body weights reported in the literature. The TRV$_{LOAEL}$ was assumed to be 10-fold higher.

Methylmercury TRVs for Mink

Wobeser et al. (1976) exposed adult mink to a diet containing five dose levels (1.1 to 15 ppm) of methyl mercuric chloride for 93 days (subchronic exposure) and monitored growth and survival. Doses above 1.8 ppm were observed to cause decreases in weight gain and survival. Based on this study, Sample et al. (1996) derived a TRV$_{NOAEL}$ of 0.015 mg/kg$_{bw}$-d using the food consumption rates and body weights reported in the literature, and applying a subchronic-to-chronic uncertainty factor of 0.1. The TRV$_{LOAEL}$ was based on the 1.8 ppm dietary level, and was 0.025 mg/kg$_{bw}$-day.

2.7.12 Nickel Mammalian TRVs

The EcoSSL document for nickel (USEPA, 2007g) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data for multiple organisms (cattle, dog, meadow vole, mice and rat). The data for the meadow vole and mice were combined to derive the TRVs for the small mammal receptors. The data for the rat was used to develop the TRVs for the larger mammals (red fox and mink). These TRVs are shown below.

- Small mammals: There were 16 NOAEL and 13 LOAEL values for small mammals in the EcoSSL dataset, 7 of which represented bounded results (mouse and vole). The geometric means of the bounded TRV$_{NOAEL}$ and TRV$_{LOAEL}$ values were 20.5 and 62.7 mg/kg$_{bw}$-day, respectively.

- Rats: There were 25 NOAEL and 14 LOAEL values for rats in the EcoSSL dataset, 7 of which represented bounded results. The geometric means of the bounded TRV$_{NOAEL}$ and TRV$_{LOAEL}$ values were 6.21 and 28.8 mg/kg$_{bw}$-day, respectively.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat (**Table 2-2b**). The rat TRVs are body weight-scaled to assess potential risks in larger mammals (**Table 2-2a**).

2.7.13 Selenium Mammalian TRVs

The EcoSSL document for selenium (USEPA 2007h) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data for multiple organisms (cattle, dog, goat, hamster, mice, pig, rabbit, rat, and sheep). The data for the hamster and mice were combined to derive the TRVs for the small mammal receptors. The data for the rat was used to develop the TRVs for the larger mammals (red fox and mink). These TRVs are summarized below.

- Small mammals: There were 53 NOAEL and 39 LOAEL values for small mammals in the EcoSSL dataset, 27 of which represented bounded results (hamster and mouse). The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values were 0.91 and 2.0 mg/kg_{bw}-day, respectively.

- Rats: There were 73 NOAEL and 95 LOAEL values for rats in the EcoSSL dataset, 37 of which represented bounded results. Geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values were 0.38 and 0.75 mg/kg_{bw}-day, respectively.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat (**Table 2-2b**). The rat TRVs are body weight-scaled to assess potential risks in larger mammals (**Table 2-2a**).

2.7.14 Silver Mammalian TRVs

The EcoSSL document for silver (USEPA 2006) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset was limited for silver and included NOAEL and LOAEL data for only two mammals (rats and pigs). The values for the rats (one NOAEL and 3 LOAELS, all unbounded) were used to develop the TRVs for all of the mammalian species.

- Rats: TRV_{NOAEL} of 116 mg/kg_{bw}-day and geometric mean TRV_{LOAEL} 138 mg/kg_{bw}-day.

These TRVs were body weight-scaled to derive TRVs for small mammals (**Table 2-2b**) and large mammals other than mink (**Table 2-2a**).

2.7.15 Vanadium Mammalian TRVs

The EcoSSL document for vanadium (USEPA 2005g) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data for multiple organisms (guinea pig, mouse, pig, rat and sheep). The data for the guinea pig and mouse were combined to derive the TRVs for the small mammal receptors. The data for the rat was used to develop the TRVs for the larger mammals (red fox and mink). These TRVs are summarized below.

- Small mammals: There were 6 NOAEL and 5 LOAEL values for small mammals in the EcoSSL dataset, three of which represented bounded results (mouse only). The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values were 4.16 and 8.31 mg/kg_{bw}-day, respectively.

- Rats: There were 17 NOAEL and 17 LOAEL values for rats in the EcoSSL dataset, four of which represented bounded results. Geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values were 0.93 and 9.11 mg/kg_{bw}-day, respectively.

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat (**Table 2-2b**). The rat TRVs are body weight-scaled to assess potential risks in larger mammals (**Table 2-2a**).

2.7.16 Zinc Mammalian TRVs

The EcoSSL document for zinc (USEPA 2007i) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data for multiple organisms (cattle, hamsters, horse, mink, mice, pig, rabbit, rat, sheep and water buffalo). The data for the hamster and mice were combined to derive the TRVs for the small mammal receptors. The largest number of results was available for the rat, so this species was used to develop the TRVs for the species other than the mink. The mink studies were used to derive the mink TRVs and the rat data were used to develop the TRVs for the red fox after body weight scaling.

- Small mammals: There were 22 NOAEL and 6 LOAEL values for small mammals in the EcoSSL dataset, six of which represented bounded results (mouse only). Geometric mean of six bounded TRV_{NOAEL} and TRV_{LOAEL} values were 561 and 4,479 mg/kg_{bw}-day, respectively.

- Rats: There were 35 NOAEL and 17 LOAEL values for rats in the EcoSSL dataset, three of which represented bounded results. Geometric mean of three bounded TRV_{NOAEL} and TRV_{LOAEL} values were 215 and 1,419 mg/kg_{bw}-day, respectively.

- Mink: Only NOAEL values were available. The geometric mean of the six TRV_{NOAEL} values was 160 mg/kg_{bw}-day. The TRV_{LOAEL} was assumed to be 10-fold higher (1,600 mg/kg_{bw}-day).

The small mammals TRVs will be used to assess potential risks to short-tailed shrew and meadow vole, and are body weight-scaled for the little brown bat (**Table 2-2b**). The rat TRVs are body weight-scaled to assess potential risks in larger mammals, except for the mink (**Table 2-2a**).

3 AVIAN TRVS

The avian species that will be evaluated in the BERA include the following: American robin, great blue heron, mallard duck, red-tailed hawk, and tree swallow. When possible, a separate set of TRVs were developed to support the evaluation of potential mallard duck risks in the BERA. The primary data sources for the avian TRVs are the EcoSSL documents.

Table 3-1a compiles the literature sources used to derive the avian TRVs for species other than ducks and **Table 3-1b** compiles the same for the duck. The derivation of avian TRVs for the COPECs that will be evaluated in the BERA is discussed below.

3.1 AVIAN TRVS FOR PHTHALATES

3.1.1 BEHP Avian TRVs

Peakall et al. (1974) exposed ringed doves to one test diet containing 10 ppm of BEHP for four weeks. There were no significant reproductive effects at this test dose. Sample et al. (1996) assumed a body weight of 0.155 kg and food consumption rate of 0.01727 kg/day to derive a TRV_{NOAEL} value of 1.11 mg/kg-day. A TRV_{LOAEL} could not be derived from this study.

3.1.1 BBP Avian TRVs

A review of the literature showed no relevant avian toxicity data for BBP. Therefore, the TRV_{NOAEL} derived for BEHP will also be used to assess BBP.

3.2 AVIAN TRVS FOR PAHS

As with the mammalian receptors, the EcoSSL document for PAHs (USEPA 2007a) was used as the primary source for toxicity data for this class of COPECs. The Eco-SSL report divided PAHs into two groups: low molecular weight PAHs (L-PAHs) and high molecular weight PAHs (H-PAHs). Of the PAHs retained as COPECs, acenaphthylene is considered to be an L-PAH while the remaining PAHs that are COPECs are considered H-PAHs (ATSDR, 1995).

3.2.1 Avian TRVs for Low-Molecular Weight PAHs

The EcoSSL dataset for L-PAHs included NOAEL data from one study using the bobwhite quail (*Colinus virginianus*). Naphthalene was the only L-PAH that was reported. Juvenile birds were exposed to a control diet or six diets containing naphthalene (316, 562, 1,000, 1,780, 3,160 and 5,620 ppm) for 5 days. There were no growth or survival effects at any of the doses. After adjusting for body weight and ingestion rate, the calculated TRV was 1,653 mg/kg-day. This is considered to be a subchronic exposure, so the TRV_{NOAEL} was one-tenth this value (165 mg/kg_{bw}-day). A LOAEL was not reported, but was assumed to ten times the TRV_{NOAEL} value. These TRVs were used for the single L-PAH that is considered a COPEC (naphthalene).

3.2.2 Avian TRVs for High-Molecular Weight PAHs

The EcoSSL dataset for H-PAHs included NOAEL and LOAEL data from one study using the European starling (*Sturnus vulgaris*). A single H-PAH [7,12- Dimethylbenz(a)anthracene] was the only PAH that was reported in this study. Juvenile birds were exposed to a control diet or two doses (2 and 20 mg/kg_{bw}-day) containing this H-PAH for 5 days. Growth effects were not observed at the lower dose but were observed at the higher dose. Because the birds were tested for only five days, this is considered to be a subchronic exposure, so the TRV_{NOAEL} was one-tenth the NOAEL (0.2 mg/kg_{bw}-day) and the TRV_{LOAEL} was one tenth the LOAEL (2 mg/kg_{bw}-day). These TRVs were used for the remaining H-PAHs that are assumed to be COPECs.

The H-PAH TRVs are in reasonably good agreement with the TRVs that would be estimated based on toxicity studies by Schaefer et al. (1983). Schafer et al. (1983) reported the LD_{50}s for numerous chemicals, including several of the PAHs, for red-winged blackbirds and European starlings. These were developed using acute toxicity methods commonly used at that time, with exposure by oral gavage or oral intubation. The H-PAH LD_{50}s were approximately 100 mg/kg-day. Application of the 1,000-fold adjustment factor (to convert from an LD_{50} to a NOAEL) yields a TRV_{NOAEL} on the order of 0.1 mg/kg_{bw}-day, which is similar to that reported in the EcoSSL dataset. The latter values were used for the BERA as there is less uncertainty in the testing protocol.

3.3 AVIAN TRVS FOR PENTACHLOROPHENOL

The EcoSSL document for pentachlorophenol (USEPA 2007b) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data for a chicken and duck. TRVs were developed for all species excluding ducks and for ducks only.

- Avian species other than duck: There were 2 NOAEL and 2 LOAEL values available for avian species other than duck, one of which represented bounded results. The bounded TRV_{NOAEL} and TRV_{LOAEL} values are 6.73 and 67.3 mg/kg_{bw}-day, respectively.

- Duck: There were 2 NOAEL and 1 LOAEL values available for the duck available in the EcoSSL dataset, one of which represented bounded results. The bounded TRV_{NOAEL} and TRV_{LOAEL} values are 40.9 and 92.9 mg/kg_{bw}-day, respectively.

3.4 AVIAN TRVS FOR PESTICIDES

There were 20 pesticides retained for further evaluation in the BERA. These fall into seven groups that representative different isomers (e.g., DDx compounds) or represented structurally similar compounds (e.g., endrin, endrin aldehyde and endrin ketone). The studies included in the TRV derivations are briefly discussed below.

3.4.1 Avian TRVs for DDD, DDE, DDT and total DDx

The EcoSSL document for DDT and metabolites (USEPA, 2007c was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included data for DDD, DDE and DDT. These are combined to ensure the availability of sufficient data to develop TRVs. The EcoSSL dataset included NOAEL and LOAEL data for a large number of avian species, including ducks. TRVs were developed for all species excluding ducks and for ducks only.

- Avian species other than duck: There were 109 NOAEL and 77 LOAEL values available for avian species other than duck. These included 33 bounded NOAEL and LOAEL values. The geometric means of the TRV_{NOAEL} and TRV_{LOAEL} values are 4.10 and 14.6 mg/kg_{bw}-day, respectively.

- Duck: There were 14 NOAEL and 32 LOAEL values available for the duck available in the EcoSSL dataset, eight of which represented bounded results. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 0.521 and 3.40 mg/kg_{bw}-day, respectively.

The uncertainty assessment in the BERA will evaluate the impact of TRVs based on use of DDE, DDD and DDT isomers on the calculated risks.

3.4.2 Avian TRVs for Aldrin and Dieldrin

The EcoSSL dataset for dieldrin (USEPA 2007d) included NOAEL and LOAEL data for 11 avian species, predominantly chicken, Japanese quail, ring-necked pheasant and mallard duck chicken and mallard duck. TRVs were developed for all species excluding ducks and for ducks only.

- Avian species other than duck: There were 40 NOAEL and 30 LOAEL values available for avian species other than duck. These included 18 bounded NOAEL and LOAEL values. The geometric means of the TRV_{NOAEL} and TRV_{LOAEL} values are 0.75 and 1.61 mg/kg_{bw}-day, respectively.

- Duck: There were 6 NOAEL and 7 LOAEL values available for the duck available in the EcoSSL dataset, four of which represented bounded results. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 0.236 and 2.44 mg/kg_{bw}-day, respectively.

3.4.3 Avian TRVs for *alpha*-Chlordane and *gamma*-Chlordane

Stickel et al. (1983) fed red-winged blackbirds a control diet or three test diets containing 10, 50 and 100 mg/kg of a chlordane mixture[9] for 84 days. There were no adverse effects on survival at the lowest test dose with mortality rates of 26% and 24% observed at the 50 and 100 mg/kg doses, respectively. Using an assumed ingestion rate (0.0137 kg/day) and body weight from the original study (0.064 kg), Sample et al. (1996) calculated a TRV_{NOAEL} and TRV_{LOAEL} of 2.14 and 10.7 mg/kg_{bw}-day, respectively.

These TRVs will be used for all avian species for both *alpha*- and *gamma*-chlordane. These are the same TRVs that were used in the BERA Work Plan (Integral 2016).

3.4.4 Avian TRVs for *beta*-BHC, *delta*-BHC and *gamma*-BHC (Lindane)

Chakravarty and Lahiri (1986) exposed mallard ducks by oral intubation to 20 mg/kg-day of lindane (*gamma*-BHC) for eight weeks and monitored reproductive success. Mallards exposed to this single test dose exhibited reduced eggshell thickness, laid fewer eggs and had longer time intervals between egg laying. Therefore, the test dose represents the TRV_{LOAEL}. A TRV_{NOAEL} could not be calculated from this study, but Sample et al. (1996) assumed that it would be one-tenth the TRV_{LOAEL} (i.e., 2 mg/kg_{bw}-day).

These TRVs will be used for all avian species for all three isomers of BHC. These are the same TRVs that were used in the BERA Work Plan (Integral 2016).

3.4.5 Avian TRVs for Endosulfan I and Endosulfan sulfate

Abiola (1992) fed gray partridges a control diet or three test diets containing 5, 25 and 125 mg/kg of endosulfan for four weeks. There were no adverse effects on reproduction at any of the test concentrations, therefore the maximum test dose represents the NOAEL dose. Sample et al. (1996) calculated a TRV_{NOAEL} of 10 mg/kg_{bw}-day assuming an ingestion rate (0.032 kg/day) and body weight from the original study (0.4 kg). A TRV_{LOAEL} could not be calculated from this study.

This TRV will be used for all avian species for endosulfan I and endosulfan sulfate. This is the same TRVs that were used in the BERA Work Plan (Integral 2016).

[9] The chlordane mixture was HCS-3260, which was a mixture of ~71% cis-chlordane and ~24% trans-chlordane.

3.4.6 Avian TRVs for Endrin, Endrin aldehyde and Endrin ketone

An EcoSSL document was not available for endrin and its related compounds. Therefore, a literature review was performed. Studies using species other than ducks and two studies using ducks evaluated growth, reproduction or survival endpoints for endrin and similar compounds were identified. These are summarized below and presented in **Table 3-2**.

DeWitt (1956) evaluated the toxicity of endrin to ring-necked pheasants. Birds were fed diets containing one of four doses of endrin (0.5, 1, 2, and 10 mg/kg in diet) for 120 days. Birds feed diets at the maximum test dose exhibited 100% mortality, but there was no mortality at the lower test dose. Therefore, the survival NOAEL and LOAEL doses were 2 and 10 mg/kg in the diet. Some of the evaluated reproduction endpoints (eggs per hen, percent fertility) were affected only at the maximum test dose, but there was a dose-related decline in percent hatch. Chick survival was affected only at the maximum test dose. Unfortunately, statistical analyses of these results were not performed by the authors to verify whether the differences were significant. Balancing the hatchability success with the chick survival, a LOAEL of 2 mg/kg in the diet was identified. The NOAEL is the next lowest dose (1 mg/kg in the diet). These were converted to dose based units by assuming a daily ingestion rate of 0.0582 kg/day [calculated from body weight using "all birds" allometric equation from Nagy (1987)] and body weight of 1 kg (Sample et al. 1996), the corresponding survival TRV_{NOAEL} and TRV_{LOAEL} are 0.116 and 0.582mg/kg_{bw}-day (respectively). The reproduction TRV_{NOAEL} and TRV_{LOAEL} values are 0.058 and 0.116 mg/kg_{bw}-day (respectively).

Fleming et al. (1982) exposed screech owls in the diet to a single test dose of endrin (0.75 mg/kg in diet) for more than 83 days. Egg production and hatching success were reduced at this test dose, which represents a LOAEL. Sample et al. (1996) assumed daily ingestion rate of 0.025 kg/day and body weight of 0.181 kg to derive a TRV_{LOAEL} of 1.035E-01 mg/kg_{bw}-day, and assumed the TRV_{NOAEL} would be one-tenth this value (1.035E-02 mg/kg_{bw}-day).

Roylance et al., (1985) evaluated the potential reproductive toxicity of endrin in mallard ducks. Female and male ducks were administered a control diet or two diets containing 0.5 or 3.0 mg/kg for a 12-week oviposition period (sensitive exposure period). Fertility (egg production) and egg hatchability were not affected at any dose, but there was an approximate 10% decline in embryo survival at the maximum test dose. The latter represents the LOAEL while the next lowest dose (0.5 mg/kg in the diet) is the NOAEL. Based on an estimated ingestion rate [0.125 kg/day) and estimated body weight from review of the figures in this study (1.25 kg), the calculated TRV_{NOAEL} and TRV_{LOAEL} values are 0.05 and 0.3 mg/kg_{bw}-day (respectively).

Spann et al. (1986) fed mallard ducks a control diet and two test diets containing 1 and 3 mg/kg_{dw} for approximately 227 days. Birds fed 1 mg/kg_{dw} of endrin were comparable to controls for survival, body weights and reproductive success, exhibiting greater hatching success than the control birds. Birds fed the 3 mg/kg_{dw} diet had slightly reduced (but not statistically significant) reproductive success relative to controls. Sample et al. (1996) considered the maximum test dose to be the NOAEL. Based on their assumed ingestion rate (0.115 kg/day) and body weight from the original study (1.15 kg) a TRV_{NOAEL} of 0.3 mg/kg_{bw}-day is calculated. A TRV_{LOAEL} could not be calculated from this study.

- Avian species other than duck: The NOAEL and LOAEL values from the study by Dewitt (1965) and Fleming et al. (1982) were used to develop the TRVs. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 0.041 and 0.19 mg/kg_{bw}-day, respectively.

- Duck: NOAEL and LOAEL values from the studies by Roylance et al. (1985) and Spann et al. (1996) were combined to develop the TRVs. The geometric means of the TRV_{NOAEL} and TRV_{LOAEL} values 0.165 and 0.3 mg/kg_{bw}-day, respectively. These values include bounded and unbounded NOAEL or LOAEL values.

3.4.7 Avian TRVs for Heptachlor and Heptachlor epoxide

Avian chronic toxicity data related to growth, reproduction and survival is lacking for heptachlor and heptachlor epoxide. USEPA (1999) developed a heptachlor TRV_{NOAEL} based on an acute (5 day) LOAEL mortality study using quail by Hill and Camardese (1986). USEPA (1999) converted the acute LOAEL dose to a NOAEL dose of 0.065 mg/kg_{bw}-day by applying a factor of 0.01. The TRV_{LOAEL} value was assumed to ten times this value. These are the same TRV_{NOAEL} and TRV_{LOAEL} values that were used in the BERA Work Plan (Integral 2016).

3.5 AVIAN TRVS FOR TOTAL PCBS

TRVs for Total PCBs (calculated as sum of detected Aroclor PCBs or sum of detected PCB congeners) were derived for birds based on literature values. Avian TRVs were developed using Aroclor 1254 (because it was the predominant form of PCBs reported in the Site samples) or "environmental PCBs" that might be representative of the exposure pathways that could occur at the Site. Only those studies that were conducted over at least a 2 month period were included in this assessment. This was done because there are large number of LD_{50} toxicological studies or short term (e.g., single dose) studies that are not relevant to environmental exposures. The studies included in the TRV derivation are summarized in **Table 3-3** and briefly discussed below.

Peakall (1971) exposed ring doves (*Streptopelia risoria*) to a diet containing 10 ppm of Aroclor 1254 for 6 months and evaluated whether there was any impact on egg shell thickness (based on ashed eggshell weights) relative to a control diet. The egg shell weights of exposed and control birds were comparable. The 10 ppm represents a NOAEL. The author did not include the body weight or ingestion rates of the test organisms. Using the average body weight (0.155 kg) and ingestion rate (0.017 kg/d) reported by Sample et al. (1996), this equates to a TRV_{NOAEL} of 1.1 mg/kg_{bw}-day. A TRV_{LOAEL} could not be calculated from this study.

Dahlgren et al. (1972) exposed ring-necked pheasants (*Phasianus colchicus*) for 17 weeks via oral gavage and monitored reproduction. Two dose levels were used (12.5 and 50 mg/kg of Aroclor 1254). USEPA (2000) considered the lower dose to be a NOAEL and the upper dose the LOAEL. Adjusting to a daily dose using the average body weights of the test organisms, yielded a TRV_{NOAEL} and TRV_{LOAEL} of 1.8 and 7.1 mg/kg-d, respectively.

Heath et al. (1972) evaluated the toxicity of Aroclor 1254 in the northern bobwhite (*Colinus virginianus*) and mallard duck (*Anas platrhynchos*). Over a two year period birds were fed diets containing either 25 or 50 ppm of Aroclor 1254 and were evaluated for egg production, egg hatchability, and survival of chicks. The NOAEL for the Northern bobwhite was 50 ppm in the diet, while the NOAEL for the duck was 25 ppm (and the LOAEL was 50 ppm). Adjusting to a daily dose using the average body weights and ingestion rates of the test organisms, resulted in TRV_{NOAEL}s of 4.7 and 7 mg/kg-day for the northern bobwhite and duck (respectively), and a TRV_{LOAEL} of 7 mg/kg-d for the duck.

Platonow and Reinhart (1973) evaluated the toxicity of Aroclor 1254 in the chicken (*Gallus domesticus*). Birds were fed diets containing either 5 or 50 ppm of Aroclor 1254 for 39 weeks. The 50 ppm dose significantly reduced production of eggs and hatchability, and was replaced with the control ration after 14 weeks. The 5 ppm level of PCB reduced egg production but not hatchability of fertile eggs. Fertility of eggs in the 5 ppm group also declined after 14 weeks of exposure, but the authors reported that this was not related to PCB exposures. Therefore, the 5 ppm level represented a LOAEL. The authors did not report body weights or ingestion rates, so values reported in USEPA (1993) and Sample et al. (1996) were used to develop TRVs. The 5 ppm dose level resulted in a TRV_{LOAEL} of 0.35 mg/kg-day. A TRV_{NOAEL} could not be calculated from this study.

Peakall and Peakall (1973) evaluated the second-generation ring doves from their prior study that exposed the first-generation group to a diet containing 10 ppm of Aroclor 1254 (Peakall, 1971). The second generation doves were inconsistent in incubation of their eggs resulting in reduced hatchability. Although this is more representative of a behavioral endpoint, it is relevant to the reproductive success. The dietary value of 10 ppm was considered a LOAEL, which yielded a TRV_{LOAEL} of 1.1 mg/kg_{bw}-day using the same assumptions for ingestion rate and body weight as used for evaluating of the Peakall (1971) study. A TRV_{NOAEL} could not be calculated from this study.

Cecil et al. (1974) evaluated the toxicity of Aroclors 1242, 1248 and 1254 in the chicken (*G. domesticus*). For nine weeks birds were fed diets containing either 2 or 20 ppm of the mixed PCBs. Hatchability declined two weeks after hens were given the upper dose but there was no effect at the lower dose. Therefore, the 2 ppm dose represented the NOAEL and the 20 ppm dose represented the LOAEL. The authors did not report body weights or ingestion rates, so values reported in USEPA (1993) and Sample et al. (1996) were used to derive TRVs. The calculated TRV_{NOAEL} and TRV_{LOAEL} were 0.14 and 1.4 mg/kg_{bw}-day, respectively.

Lillie et al. (1974) evaluated the toxicity of Aroclor 1254 in the chicken (*G. domesticus*). For nine weeks birds were fed diets containing either 2 or 20 ppm of the Aroclor 1254. There were no effects to adult body weight gain, survival, egg weight, egg shell thickness or fertility at either dose level. Egg production was significantly reduced relative to control at the 20 ppm dose level. Feed consumption of adults was also depressed at this dose level, which may have contributed to the reduced egg production. Based on these results, the 2 ppm dietary level represents the NOAEL while the 20 ppm dose level represents the LOAEL. The authors did not report body weights for the 9 week exposure period, but did report the initial average body weight (1.953 kg) which was used for the TRV calculation. The authors reported a food consumption rate of 118.5 to 124.3 g/day (mean: 121.4 g/day) for the two dose levels for the 9 week period. The mean ingestion rate was used to calculate the TRVs. The calculated TRV_{NOAEL} and TRV_{LOAEL} were 0.124 and 1.24 mg/kg_{bw}-day, respectively.

Lillie et al. (1975) evaluated the toxicity of Aroclor 1254 (as well as Aroclors 1016, 1232, 1242 and 1248) in the chicken (*G. domesticus*). Birds were fed diets containing 5, 10 or 20 ppm of the Aroclor 1254 for eight weeks. There were no adverse effects on egg production, egg weight, egg shell thickness, feed consumption, adult body weight changes, survival or fertility during this exposure period. Based on these results, the 20 ppm dietary level represents the NOAEL. Using the average body weights and ingestion rates reported from their prior study (Lillie et al., 1974), the TRV_{NOAEL} was 1.24 mg/kg_{bw}-day.

Riseborough and Anderson (1975) exposed mallard ducks (*Anas platyrhynchos*) to a diet containing 40 ppm of Aroclor 1254 for approximately four months and monitored egg production, eggshell thickness and related endpoints. There were no differences between ducks fed a control diet or the 40 ppm diet on any of the measured endpoints. Based on these results, the 40 ppm dietary level represents a NOAEL. The authors did not report average body weights or ingestion rates. Therefore, the values reported by Sample et al. (1996) for these terms were used to calculate the TRV_{NOAEL} of 4.0 mg/kg_{bw}-day.

Kosutsky et al. (1979) exposed chickens to a diet containing 5 ppm of the PCB mixture Delor 105, which is 54% chlorine by weight (similar to Aroclor 1254). Birds were fed this diet for 6 weeks followed by 3 weeks of control diet. There were no differences relative to controls for egg production, egg weight or eggshell strength and weight. The authors did not report body weights or ingestion rates, so values reported in USEPA (1993) and Sample et al. (1996) were used for these terms to estimate a TRV. The calculated TRV_{NOAEL} was 0.35 mg/kg_{bw}-day.

Roberts et al. (1978) reported a study where ring-necked pheasants (*P. colchicus*) were exposed to Aroclor 1254 at a dietary concentration of 50 ppm. In their review of this study, USEPA

(2000) reported that there was a reduction in female fertility at this dose level, and a TRV_{LOAEL} of 2.9 mg/kg_{bw}-day was calculated.

Custer and Heinz (1980) exposed ducks to diets containing 25 ppm of Aroclor 1254 for one month. There was no apparent effect on reproductive success during this period. Although a TRV_{NOAEL} (7.0 mg/kg_{bw}-day) could be calculated from this study, it did not meet the minimum of 2 months exposure used to derive TRVs for this project.

Summer et al. (1996) exposed white leghorn chickens (*G. domesticus*) to diets containing carp collected from Saginaw Bay, Lake Huron, Michigan. The diets contained 0%, 3.5% or 34% carp, which yielded total PCB concentrations in the diets of 0.3, 0.8 and 6.6 mg/kg (respectively). The chickens were fed for an eight-week period, which overlapped egg-laying. Consumption rates and body weights were monitored on a biweekly basis. Food consumption rates were similar across the dose groups and exposure periods. The mean body weights decreased with increasing dose and exposure periods, although the authors did not evaluate whether these were statistically significant. On average, the daily egg production and egg weights were greater with the diets containing carp relative to control. These results would suggest a potential NOAEL for growth only at the intermediate dose level. Based on the average body weight for the intermediate dose group (1.593 kg), and their average food consumption rate (91.19 g/day), the calculated TRV_{NOAEL} is 4.6E-02 mg/kg_{bw} -day.

Custer et al. (1998) evaluated the reproductive success of tree swallows (*Tachycineta bicolor*) exposed to environmental PCBs in the Fox River and Green Bay systems. Prey items (emergent insects were collected for chemical analysis). The authors reported that there were no effects on clutch size or egg hatchability in adults that had consumed diets containing up to 0.61 mg/kg of total PCBs. Based on this information, USEPA (2000) reported a TRV_{NOAEL} of 0.55 mg/kg_{bw} -day.

Synopsis

Excluding the study by Custer and Heinz (1980), the geometric means of the TRV_{NOAEL} and TRV_{LOAEL} values for all avian species other than ducks are 0.316 and 2.32 mg/kg_{bw}-day (respectively). The bounded TRV_{NOAEL} and TRV_{LOAEL} values for ducks are from a single study (Heath et al. 1972) and are 7.0 and 14 mg/kg_{bw}-day.

3.6 AVIAN TRVS FOR PCDD/F-TEQ AND PCB-TEQ

Toxicological studies that have assessed the effects of TCDD on growth, reproduction and survival endpoints on avian species are limited. Most of the work has focused on egg injection studies that are not readily transferable to dietary exposure assessments (USEPA 2003).

Nosek et al. (1992) evaluated the toxicity and potential reproductive effects of 2,3,7,8-TCDD on ring-necked pheasants. Birds were exposed to TCDD via weekly intraperitoneal injection for a total of 10 weeks during egg formation period. Control and three doses (0.01, 0.1 and 1 μg/kg_{bw} per week) were used. Based on an assumed body weight of 1 kg, Sample et al. (1996) calculated equivalent daily doses of 1.4E-06, 1.4E-05, and 1.4E-04 mg/kg_{bw}-day, respectively. Egg production and hatchability were significantly reduced among birds receiving the maximum test dose. No significant effects relative to control were observed among the two lower dose levels. Therefore, the maximum test daily dose represents the TRV_{LOAEL} (1.4E-04 mg/kg_{bw}-day) and the next lowest test daily dose the TRV_{NOAEL} (1.4E-05 mg/kg_{bw}-day).

3.7 AVIAN TRVS FOR METALS

The avian TRVs for metals were derived from the toxicity data provided with the metal-specific EcoSSL documents or Sample et al. (1996). For the latter, the selected TRV_{NOAEL} or TRV_{LOAEL} was the geometric mean of the bounded NOAEL or LOAEL values (respectively) across (1) all species except ducks; and (2) ducks only, except where noted. The derivation of the avian TRVs are briefly summarized below.

3.7.1 Antimony Avian TRV

The EcoSSL document for antimony (USEPA 2005a) did not include any avian toxicity data. A review of alternate data sources (EPA Ecotox database; Sample et al., 1996) did not identify any appropriate toxicity values to develop a TRV. Therefore, an avian TRV for antimony could not be developed for the BERA.

3.7.2 Arsenic Avian TRVs

The EcoSSL document for arsenic (USEPA 2005b) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data for chicken and mallard duck. The data for the species other than duck (4 NOAELs and 1 LOAEL) and duck (2 NOAELs and 1 LOAEL) were very limited. Geometric means of the NOAEL and LOAEL values for the duck yielded a larger TRV_{NOAEL} (8.02 mg/kg_{bw}-day) than TRV_{LOAEL} (5.08 mg/kg_{bw}-day) due to the limited LOAEL data. Therefore, the geometric means across all of the test organisms will be used in the BERA to assess the avian species.

- All Avian species: There were 6 NOAEL and 2 LOAEL values available for all avian species, none of which represented bounded results. The geometric means of the TRV_{NOAEL} and TRV_{LOAEL} values are 3.70 and 4.51 mg/kg_{bw}-day, respectively.

An evaluation of the use of "all avian species" for the assessment of potential risks from arsenic will be presented in the BERA uncertainty assessment.

3.7.3 Barium Avian TRVs

There were no avian TRVs reported in the EcoSSL document (USEPA, 2005c). Consequently, an alternate data source was used.

Johnson et al. (1960) exposed one-day-old chicks for four weeks to a diet containing barium hydroxide and monitored survival. Eight dose levels up to 32,000 ppm were evaluated. Chicks exposed to dosage ranging from 4,000 to 32,000 ppm barium experienced mortality, which ranged from 5% to 100%. Based on this study and assumptions regarding average body weights and ingestion rates of the chicks, Sample et al. (1996) derived a TRV_{NOAEL} of 20.8 mg/kg_{bw}-day and a TRV_{LOAEL} of 41.7 mg/kg_{bw}-day. These TRVs (based on the chick) were factors of ten lower than the original estimated subchronic NOAEL and LOAEL.

3.7.4 Cadmium Avian TRVs

The EcoSSL document for cadmium (USEPA 2005d) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data for multiple organisms (chicken, Japanese quail, mallard duck, wood duck). TRVs were developed for all species excluding ducks and for ducks only.

- Avian species other than duck: There were 21 NOAEL and 28 LOAEL values available for avian species other than duck. Of these, there were 11 studies with bounded NOAEL and LOAEL values. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 2.03 and 5.96 mg/kg_{bw}-day, respectively.

- Duck: There were 11 NOAEL and 4 LOAEL values available for the duck available in the EcoSSL dataset, three of which represented bounded results. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 3.08 and 25.6 mg/kg_{bw}-day, respectively.

3.7.5 Chromium Avian TRVs

The EcoSSL document for chromium (USEPA, 2008) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data mostly for chicken, but also black duck and turkey. TRVs were developed for all species excluding ducks and for ducks only.

- Avian species other than duck: There were 14 NOAEL and 3 LOAEL values available for avian species other than duck. Of these, only one study reported bounded NOAEL and LOAEL values. The bounded TRV_{NOAEL} and TRV_{LOAEL} values are 37.7 and 75.4 mg/kg_{bw}-day, respectively.

- Duck: There were two NOAEL and two LOAEL values available for the duck available in the EcoSSL dataset, both of which represented bounded results. The geometric mean of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 0.56 and 2.8 mg/kg_{bw}-day, respectively.

3.7.6 Cobalt Avian TRVs

The EcoSSL document for cobalt (USEPA 2005e) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data for chicken and ducks. TRVs were developed for all species excluding ducks and for ducks only.

- Avian species other than duck: There were 9 NOAEL and 10 LOAEL values available for avian species other than duck. Of these, there were 5 bounded NOAEL and LOAEL values. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 5.45 and 11.1 mg/kg_{bw}-day, respectively.

- Duck: There were two NOAEL and two LOAEL values available for the duck available in the EcoSSL dataset, one of which represented bounded results. The bounded TRV_{NOAEL} and TRV_{LOAEL} values are 14.8 and 148 mg/kg_{bw}-day, respectively.

3.7.7 Copper Avian TRVs

The EcoSSL document for copper (USEPA 2007e) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data mostly for chicken, but also mallard duck, Japanese quail, and turkey. TRVs were developed for all species excluding ducks and for ducks only.

- Avian species other than duck: There were 163 NOAEL and 98 LOAEL values available for avian species other than duck. Of these, there were 67 bounded NOAEL and LOAEL values. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 20.1 and 36.0 mg/kg_{bw}-day, respectively.

- Duck: There were 8 NOAEL and 5 LOAEL values available for the duck available in the EcoSSL dataset, two of which represented bounded results. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 24.1 and 75.0 mg/kg_{bw}-day, respectively.

3.7.8 Cyanide Avian TRVs

An EcoSSL document for cyanide was not available. An EcoSSL document for cyanide was not available. Much of the literature regarding avian cyanide toxicity has focused on acute or subchronic exposures or reported LD_{50} results (e.g., Eisler 1991).

Wiemeyer et al. (1986) exposed domestic chicken, eastern screech-owl, black vulture, American kestrel, Japanese quail, and European starling to various dose rates of sodium cyanide to observe lethality. Cyanide was administered via oral capsule. Exposed birds showed acute LD_{50} ranging from 4.0 to 21 mg/kg_{bw}. All observations of toxic outcomes were determined the same day as the oral dose (i.e., single dose is equivalent to a daily dose). The geometric mean LD_{50} across the test species was 10.4 mg/kg_{bw}-day. Based on this study, a TRV_{NOAEL} of 0.14 mg/kg_{bw}-day was calculated applying a factor of 1/100 to the geometric mean value. The TRV_{LOAEL} was assumed to be a factor of 10 times higher than the TRV_{NOAEL}, and therefore, 1.40 mg/kg_{bw}-day.

3.7.9 Lead Avian TRVs

The EcoSSL document for lead (USEPA 2005f) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data mostly for chicken, but also duck, Japanese quail, pigeon, American kestrel, and goose. TRVs were developed for all species excluding ducks and for ducks only.

- Avian species other than duck: There were 31 NOAEL and 39 LOAEL values available for avian species other than duck. Of these, there were 18 bounded NOAEL and LOAEL values. The bounded TRV_{NOAEL} and TRV_{LOAEL} values are 10.5 and 53.8 mg/kg_{bw}-day, respectively.

- Duck: For the duck there were only 5 NOAEL results available in the EcoSSL dataset. The geometric mean TRV_{NOAEL} was 16.6 mg/kg_{bw}-day, respectively. An uncertainty factor to convert this value to the TRV_{LOAEL} can be estimated from the ratio of the bounded TRV_{NOAEL} and TRV_{LOAEL} (53.8/10.5 = 5.12). Therefore, the TRV_{LOAEL} for the duck was estimated to be 85.0 mg/kg_{bw}-day.

3.7.10 Manganese Avian TRVs

The EcoSSL document for manganese (USEPA 2007f) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data mostly for chicken, but also Japanese quail and turkey. TRVs were developed across all of the species in the EcoSSL dataset.

- All Avian species: There were 26 NOAEL and 3 LOAEL values available for avian species. Of these, there were three bounded NOAEL and LOAEL values. The bounded TRV_{NOAEL} and TRV_{LOAEL} values are 257 and 377 mg/kg_{bw}-day, respectively.

No toxicity data for ducks were reported in the EcoSSL dataset so the "all avian species" bounded TRV_{NOAEL} and TRV_{LOAEL} values will be used to assess duck risks for the BERA.

3.7.11 Mercury Avian TRVs

TRV were derived for both inorganic mercury and organic methyl-mercury based on a review of the literature. An EcoSSL document was not available for either inorganic or organic mercury.

Inorganic Mercury Avian TRVs

Hill and Shaffner (1976) exposed Japanese quail for one year to a diet containing mercuric chloride and monitored reproduction. Dose levels up to 32 mg/kg_{bw}-d were evaluated. Adverse effects to quail reproduction were observed at 8 mg/kg_{bw}-d. Based on this study, Sample et al. (1996) derived a TRV_{NOAEL} of 0.45 mg/kg_{bw}-d and a TRV_{LOAEL} of 0.9 mg/kg_{bw}-d.

Methyl Mercury Avian TRVs

Table 3-4 compiles the studies used to develop the avian TRVs for methyl mercury, which are summarized below.

Custer et al. (2007) assessed trace element exposure and reproduction in tree swallows at four sites along the Carson River, NV. Three nest boxes were placed downstream of mine and milling sites, and one nest box was placed upstream of these sites. Nests were monitored weekly for number of eggs and number of nestlings from mid-May through early July for two years. Researchers collected two eggs per clutch for trace element analysis, and two 10-12 day old nestlings for stomach content and tissue analysis.

Total mercury and seven other trace elements (Al, B, Cu, Fe, Mg, Mn, Zn) were detected in >95% of samples. Tree swallow eggs and livers from the downstream sites had total mercury concentrations 15-40 times greater than the reference site. Total mercury was detected in the stomach contents of all downstream samples (geometric mean of 1.17 mg/kg_{dw}), and was undetected in stomach content samples from the reference site. At the three downstream sites, mean hatching success was 74% for tree swallows. Clutches with lower rates of hatching success on average had higher total mercury egg concentrations than clutches with 100% hatching success, but means did not differ significantly. Logistic and linear regressions found no relationship between total mercury concentration and hatching success in tree swallows. In addition to tree swallows, Custer et al. (2007) studied house wren at the reference site and one downstream site, but not provide summary statistics. Therefore, only results for tree swallow could be used for TRV derivation. The 1.17 mg/kg dose group was selected as the dietary NOAEL for tree swallows. Based on an assumed body weight of 0.0202 kg (Nagy 2001) and ingestion rate of 0.0049 kg/day (dry weight allometric equation for passerines from Nagy (2001)), the TRV_{NOAEL} for this study is 0.28 mg/kg_{bw}-day.

Longcore et al. (2007) monitored reproduction and measured total mercury in food bolus, eggs, and tissues of wild tree swallows at three locations in the U.S. Northeast: Mount Desert Island, ME, Orono, ME (control), and Ayer, MA (positive control). Nest boxes were constructed in close proximity to freshwater ponds at all sites in early April, and boxes were monitored throughout spring for reproductive performance as measured by hatching success and fledging success. Monitoring of nest boxes occurred for one to three breeding seasons depending on the site. At the two Maine sites (Mount Desert Island and Orono), the third egg of each clutch was collected for mercury analysis, and at the Massachusetts site (Ayer), the first three eggs of every clutch were collected for analysis after four eggs were laid. At all sites food bolus was collected from nestlings 6 to 9 days after hatch. In addition, one older nestling from each clutch (minimum 14 days old) was collected for tissue analysis.

Mean total mercury concentration in food bolus samples from contaminated ranged from 128 to 291 ng/g_{ww}. Both the minimum and maximum food bolus mercury concentrations were recorded at Mount Dessert Island ponds. Reproductive success at all sites was unaffected by dietary total mercury. Mean percent of eggs hatched per clutch did not differ significantly among sites, and fledgling success was significantly lower only at the Orono nest boxes (reference site), where raccoon predation removed three broods. The 0.291 mg/kg (291 ng/g) dose group was selected as the dietary NOAEL. Based on an assumed body weight of 0.0202 kg (Nagy 2001) and ingestion rate of 0.22 kg/day (wet weight allometric equation for passerines from Nagy (2001)), the TRV_{NOAEL} for this study is 0.22 mg/kg_{bw}-day.

Varian-Ramos et al. (2014) assessed methyl mercury reproductive toxicity in two generations of laboratory zebra finch. Treatment groups were fed pelletized diets containing 0.0, 0.3, 0.6, 1.2 or 2.4 mg/kg wet weight methyl mercury in the form of methyl mercury cysteine. Diets contained 13.9% moisture (value attained by personal correspondence with author). F0 generation birds were dosed for 10 weeks in single sex cages and then grouped into 18 pairs per treatment level. Birds were allowed to breed for one year on the treatment diet. Chicks were kept in parental cages until 50 days of age, at which point they were moved to a flock and fed the treatment diet. Before reaching 400 days of age, birds from the F1 generation were divided into 18 non-sibling pairs per treatment group. Dosing continued for the lifespan of the F1 generation. Birds were monitored daily for reproductive success as measured by number of offspring, number of eggs per clutch, proportion of eggs hatched, proportion of chicks fledged, days to re-nest, and proportion survival. Blood mercury was measured in each bird on a monthly basis, and egg mercury concentrations were analyzed in eggs of the first clutch produced by every pair.

Combining the results from both generations, all treatment levels resulted in significantly fewer offspring compared to the control. Reduction in offspring was 16%, 31%, 42%, and 50% for the 0.3, 0.6, 1.2, and 2.4 mg/kg groups, respectively. Fledging success was also significantly reduced in all treatment groups compared to the control. Latency to re-nest was significant at and above the 0.6 mg/kg level. Hatching success was higher in the 0.3 mg/kg group than the control, but lower at the 2.4 mg/kg level. Clutch size and adult survival were not affected by methyl mercury treatment. The 0.3 mg/kg dose group was selected as the dietary LOAEL for this study. Using an assumed body weight of 0.013 kg[10] and ingestion rate of 0.0036 kg/day (dry weight allometric equation for passerines from Nagy (2001)), the TRV_{LOAEL} for this study is 0.097 mg/kg_{bw}-day.

Elliot et al. (1989) evaluated great blue heron reproduction at four colonies in British Columbia from 1986-1987. Nests were monitored for clutch size and the number of young fledged per successful nest (defined as a nest with at least one fledgling). In 1986, one egg per nest and regurgitated food bolus from nestlings were analyzed for contaminant concentrations.

Study authors assessed the relationship between contaminant doses and responses and the four sites. Multiple chemicals were evaluated including dioxins, furans, PCBs, organochlorine pesticides, and mercury. The average concentration of total mercury in regurgitated food bolus in 1986 was 0.03 mg/kg wet weight (range: 0.015 to 0.50 mg/kg_{ww}). In the same year, there was no significant difference among sites in clutch sizes and the mean number of young fledged per successful nest. Therefore, 0.03 mg/kg was selected as the dietary NOAEL. Using an assumed body weight of 2.23 kg (Quinney 1982) and ingestion rate of 0.51 kg/day (wet weight allometric equation for carnivorous birds from Nagy (2001)), the TRV_{NOAEL} for this study is 0.0075 mg/kg_{bw}-day.

Frederick and Jayasena (2011) and Frederick et al. (2011) assessed methyl mercury toxicity in white ibis nestlings captured from breeding colonies in south Florida. Nestlings were randomly divided into four groups of 20 pairs and were dosed with 0, 0.05, 0.1, and 0.3 mg/kg wet weight methyl mercury, which was sprayed onto pelletized feed using a corn oil vehicle. Dosing began when birds were 90 days old and continued for three years. Frederick et al. (2011) reported on white ibis survival in captivity and in the wild after depuration. Frederick and Jayaena (2011) reported on courtship behavior and reproductive success over two breeding seasons.

Methyl mercury exposure was found to have no effect on white ibis survival in captivity or in the wild after depuration. Nestling production by males was lower for all treatment levels compared to controls for the two years assessed. Females nestling production, however, was significantly lower in only the low and high dose groups compared to controls for the first year, and only in the high dose group compared to controls for the second year. Though not statistically significant, low dose females fledged 33.5% fewer young than controls, and high dose females fledged 34.8% fewer young than controls. Due to the absence of a dose-response relationship between methyl mercury exposure and reproductive effects, the high dose group (0.3 mg/kg) was selected as the dietary NOAEL. Using an assumed body weight of 0.9 (midpoint of range from Cornell Lab of Ornithology) and ingestion rate of 0.28 kg/day (wet weight allometric equation for carnivorous birds from Nagy (2001)), the TRV_{NOAEL} for these studies is 0.094 mg/kg_{bw}-day.

[10] This is the average of the body weight range (10 to 16 g) reported for the zebra finch at this URL: http://lafeber.com/vet/basic-information-sheet-for-the-finch/

Henny et al. (2002) measured body weights of black-crowned night heron and snowy egrets from contaminated sites along the Carson River, Nevada and from a reference area. Six adults and six fledglings were collected for weighing and stomach content analysis from contaminated sites and from reference sites in 1997 and 1998. Weight results, however, are only reported for 1998. Nests were monitored for reproductive success, but this endpoint was not statistically evaluated.

Methyl mercury in stomach content samples from contaminated sites in 1998 ranged from 0.39 – 0.57 mg/kg_{ww} in black-crowned night heron and from 0.43 to 1.12 mg/kg_{ww} in snowy egrets. Methyl mercury concentrations in stomach contents were not reported for reference sites. Mean body weight was significantly higher in black-crowned night heron at the contaminated sites versus at the reference sites (contaminated = 724g; reference = 594g). Body weights did not differ significantly between sites for snowy egrets fledglings and for adults of both species. The 0.39 mg/kg dose group was selected the dietary LOAEL for the black-crowned night heron, and 1.12 mg/kg was selected as the dietary NOAEL for the snowy egret. A TRV_{LOAEL} of 0.13 mg/kg_{bw}-day for the black-crowned night heron was calculated using an assumed body weight of 0.79 kg (average value from study) and ingestion rate of 0.26 kg/day (wet weight allometric equation for carnivorous birds from Nagy (2001)). A TRV_{NOAEL} of 0.45 mg/kg_{bw}-d for the snowy egret was calculated using an assumed body weight of 0.42 kg (average value from study) and ingestion rate of 0.17 kg/day (wet weight allometric equation for carnivorous birds from Nagy (2001)).

Heinz (1979) exposed mallard duck for 3 generations (>1 year) to a diet containing methyl mercury dicyandiamide and monitored reproduction. Only one dietary dose level was administered (0.5 mg/kg_{dw} in food). Because adverse effects to duck reproduction were observed at this dose level, Heinz (1979) reported a dietary LOAEL of 0.5 mg/kg. Based on this study, Sample et al. (1996) derived a TRV_{LOAEL} of 0.064 mg/kg_{bw}-d based on assumed ingestion rate (128 g/d) and body weight (1 kg).

Albers et al. (2007) assessed reproduction in captive American kestrels exposed to methyl mercuric chloride at dietary concentrations of 0 (control), 0.7, 2.0, 3.3, 4.6, or 5.9 mg/kg_{dw}. Exposure durations ranged from 77 to 113 days. Egg production and hatching success were diminished in the 4.6 mg/kg_{ww} dose group. Fledging success was diminished at all dose levels, with total fledging failure observed in the two highest dose groups. The 0.7 mg/kg_{ww} dose group was selected as the dietary LOAEL for this study. Based on an assumed body weight of 0.1225 kg (midpoint of range for American kestrels from Cornell Lab of Ornithology) and an ingestion rate of 0.021 (calculated using Nagy (2001) dry weight allometric equation for carnivorous birds), the calculated TRV_{LOAEL} for this study is 0.12 mg/kg_{bw}-d.

Heinz (1974) exposed mallard duck breeding pairs to mercury dicyandiamide at dietary concentrations of 0 (control), 0.6, and 3.4 mg/kg_{dw}. Eggs were collected, incubated, and hatched, and ducklings were maintained on the same diet as their parents until reaching 20 weeks of age.

Adult survival was not affected by mercury exposure. Hatching success and duckling survival were significantly reduced at the 3.4 mg/kg dietary concentration. Therefore this concentration was selected as the dietary LOAEL and the 0.6 mg/kg concentration was selected as the dietary NOAEL. Using an assumed ingestion rate (128 g/d) and body weight (1 kg) from Sample et al. (1996), the TRV_{LOAEL} for this study is 0.44 mg/kg_{bw}-d and the TRV_{NOAEL} is 0.077 mg/kg_{bw}-d.

Heinz (1976) exposed mallard ducks to mercury dicyandiamide at dietary concentrations of 0 (control), 0.5, and 2.9 mg/kg_{dw}. Females were maintained on the treatment diet for over one year, and males received the treatment diet for approximately four months. Eggs were collected, incubated, and hatched. All ducklings were maintained on control diets. No effect was observed on adult survival, eggshell thickness, or hatching success. Duckling survival was significantly reduced in the 2.9 mg/kg dose group, which was selected as the dietary LOAEL for this study. Using an assumed ingestion rate (128 g/d) and body weight (1 kg) from Sample et al. (1996), the TRV_{LOAEL} for this study is 0.37 mg/kg_{bw}-day and the TRV_{NOAEL} is 0.064 mg/kg_{bw}-day.

Synopsis

The following TRVs will be used to assess methyl mercury exposure in birds:

- Avian species other than duck: There were 4 NOAEL and 6 LOAEL values available for avian species other than duck, none of which represented bounded results. The geometric means of the TRV_{NOAEL} and TRV_{LOAEL} values are 0.120 and 0.156 mg/kg_{bw}-day, respectively.

- Duck: For the duck there were 2 NOAEL and 3 LOAEL values available for duck, two of which represented bounded results. The geometric means of the bounded TRV_{NOAEL} and TRV_{LOAEL} values are 0.070 and 0.402 mg/kg_{bw}-day, respectively.

Table 3-4 also includes data for the tree swallow and wading birds. The tree swallow TRVs reported by Gerrard and St. Louis (2001) could not be used because the dietary concentrations were not measured. In addition, the two NOAEL and single LOAEL values for the wading birds were not bounded. An evaluation of the use of the wading bird TRVs to assess potential risks from methyl mercury to the great blue heron will be examined in the BERA uncertainty assessment.

3.7.12 Nickel Avian TRVs

The EcoSSL document for nickel (USEPA 2007g) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data mostly for chicken, but also mallard duck. TRVs were developed for all species excluding ducks and for ducks only.

- Avian species other than duck: There were 10 NOAEL and 9 LOAEL values available for avian species other than duck. Of these, there were five bounded NOAEL and LOAEL values. The bounded TRV_{NOAEL} and TRV_{LOAEL} values are 16.1 and 23.9 mg/kg_{bw}-day, respectively.

- Duck: For the duck there were 2 NOAEL and 2 LOAEL values available for duck, which included one bounded results. The bounded TRV_{NOAEL} and TRV_{LOAEL} values are 10.7 and 47 mg/kg_{bw}-day, respectively.

3.7.13 Selenium Avian TRVs

The EcoSSL document for selenium (USEPA 2007h) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data mostly for chicken, but also American kestrel, black-crowned night heron, Japanese quail, mallard duck, and owl. TRVs were developed for all species excluding ducks and for ducks only.

- Avian species other than duck: There were 56 NOAEL and 51 LOAEL values available for avian species other than duck. Of these, there were 20 bounded NOAEL and LOAEL values. The bounded TRV_{NOAEL} and TRV_{LOAEL} values are 0.547 and 1.21 mg/kg_{bw}-day, respectively, for avian species other than ducks.

- Duck: For the duck there were 36 NOAEL and 35 LOAEL values available for avian, which included 23 bounded results. The bounded TRV_{NOAEL} and TRV_{LOAEL} values are 1.29 and 3.31 mg/kg_{bw}-day, respectively.

3.7.14 Silver Avian TRVs

The EcoSSL document for silver (USEPA, 2006) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included LOAEL data only for the chicken, turkey and mallard duck. TRVs were developed for all species excluding ducks and for ducks only.

- Avian species other than duck: There were 9 LOAEL values available for avian species other than duck. The geometric mean TRV_{LOAEL} calculated from this data is 65.0 mg/kg_{bw}-day. The TRV_{NOAEL} was assumed to be one-tenth the TRV_{LOAEL}.

- Duck: For the duck there were only two study results available from EcoSSL and only LOAEL values were reported. The geometric mean TRV_{LOAEL} calculated from this data is 199 mg/kg_{bw}-day. The TRV_{NOAEL} was assumed to be one-tenth the TRV_{LOAEL}.

3.7.15 Vanadium Avian TRVs

The EcoSSL document for vanadium (USEPA 2005g) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data mostly for chickens, but also ducks and Japanese quail. TRVs were developed for all species excluding ducks and for ducks only.

- Avian species other than duck: There were 98 NOAEL and 144 LOAEL values available for avian species other than duck. Of these, there were 56 bounded NOAEL and LOAEL values. The bounded TRV_{NOAEL} and TRV_{LOAEL} values are 1.24 and 2.55 mg/kg_{bw}-day, respectively, for avian species other than ducks.

- Duck: For the duck there were only four study results available from EcoSSL and only NOAEL values were reported. The geometric mean TRV_{NOAEL} calculated from this data is 12.7 mg/kg_{bw}-day. An uncertainty factor to convert this value to the TRV_{LOAEL} can be estimated from the ratio of the bounded NOAEL and LOAEL results from the other avian species (2.55/1.24 = 2.06). Therefore, the TRV_{LOAEL} for the duck was estimated to be 26.2 mg/kg_{bw}-day.

3.7.16 Zinc Avian TRVs

The EcoSSL document for zinc (USEPA 2007i) was used as the primary source for toxicity data for this COPEC. The EcoSSL dataset included NOAEL and LOAEL data mostly for chicken, but included some results for Japanese quail, mallard duck, and turkey. TRVs were developed for all species excluding ducks and for ducks only.

- Avian species other than duck: There were 66 NOAEL and 57 LOAEL values available for avian species other than duck. Of these, there were 34 bounded NOAEL and LOAEL values. The bounded TRV_{NOAEL} and TRV_{LOAEL} values are 100.5 and 173.5 mg/kg_{bw}-day, respectively, for avian species other than ducks.

- Duck: For the ducks, there were only 5 LOAEL values available. The geometric mean TRV_{LOAEL} calculated from this data is 174 mg/kg_{bw}-day. An uncertainty factor to convert this value to the TRV_{NOAEL} can be estimated from the ratio of the bounded TRV_{LOAEL}/TRV_{NOAEL} results for the other avian species (173.5/100.5 = 1.73). Therefore, the TRV_{NOAEL} for the duck was estimated to be 101 mg/kg_{bw}-day.

4 FISH TISSUE-BASED TRV

Whole body tissue-based TRVs were developed for the bioaccumulative COPECs that were quantified in the forage fish samples – methyl mercury and Aroclor PCBs[11]. The tissue-based TRV_{NOAEL} and TRV_{LOAEL} were developed primarily from data compiled by USACE in their Environmental Residue-Effects Database (ERED). The methodology to derive the tissue-based TRVs was analogous to that used to derive EcoSSLs for soils, and is discussed below.

The ERED database groups the measurement endpoints (effects) into seven major categories: behavior, biochemical, cellular, growth, mortality, physiological, and reproduction. Biochemical effects are generally considered to be biomarkers of exposure (e.g., enzyme induction) and not an indication of an effect that may result in a reduction of the organism's fitness or fecundity. Therefore, the derivation of TRVs focused on the most ecologically relevant endpoints for the protection of fish populations: survival, reproduction, and growth. Reproductive effects include endpoints such as spawning success, fecundity, hatching success, and larval growth and survival. Behavioral and physiological responses, which are less interpretable in the context of a population-level response were not considered. The ERED database used to derive the TRVs was accessed in May 2016.

4.1 FISH TISSUE BASED TRVS FOR METHYLMERCURY

The studies used to generate the methylmercury tissue TRV_{NOAEL}s and TRV_{LOAEL}s are shown in **Table 4-1** and summarized below.

Beckvar et al. (2005) and Dillon et al. (2010) developed fish tissue effect thresholds for methylmercury based on population level effects (i.e., survival, growth and reproduction), as well as biochemical, tissue pathology and behavioral effects. Fuchsman et al. (2016) re-evaluated the underlying studies cited by Beckvar et al. (2005) and Dillon et al. (2010) and introduced several additional studies. This section assesses the studies cited by Beckvar et al. (2005), Dillon et al. (2010), and Fuchsman et al. (2016), with a focus on laboratory studies of reproduction, survival, and growth in freshwater fish. An additional study published in 2016 is included in this analysis.

Many of evaluated studies were based on measurements of total mercury in tissue. Since only methylmercury is bioaccumulative, it will be conservatively assumed that the tissue levels reflect methylmercury concentrations.

Tissue NOAELs were assigned based on mercury dose levels and the resulting tissue residue levels in treatment groups only and not in control groups. For tissue LOAEL data, the lowest

[11] Insufficient sample mass was collected for the analysis of PCB congeners or PCDD/F congeners in the forage fish samples. Other tissue benchmarks may be developed following receipt of the analytical results.

tissue residue concentration reported for an endpoint in each category (e.g., reproduction, growth, mortality) was included. Only data from adult/juvenile fish were used as early life-stage data are highly variable and not comparable to adult residue concentrations because of confounding caused by growth dilution.

Sandheinrich and Miller (2006) examined the effects of dietary methyl mercury on the reproductive behavior of fathead minnows exposed as juveniles through sexual maturity to spawning. Fish were exposed to a control diet (which contained low levels of mercury; 0.06 mg/kg_{dw}) or two treatment diets: 0.87 and 3.93 mg/kg_{dw}. Endpoints evaluated included reproductive behaviors of males (nest preparation, courtship activities, and inactivity), testosterone levels, and spawning success. Following breeding, fish were sacrificed to determine total mercury carcass concentrations. The low dose group exhibited an increase in activity related to control fish. The carcass concentrations for the low dose group averaged 0.143 mg/kg_{ww}, calculated assuming 80 percent moisture. Testosterone concentrations were not significantly different between treatments despite being positively correlated with reproductive behaviors such as nest preparation, courtship, and spawning and negatively correlated with non-reproductive behaviors. Dietary methyl mercury at the lowest test dose (0.87 mg/kg in the diet, corresponding to a tissue level of 0.143 mg/kg_{ww}) resulted in a statistically significant decrease in spawning success relative to controls. However, as noted by Fuchsman et al. (2016), control spawning rates (32-40%) were much lower than rates observed in other studies (75-100%), which suggests that results from this study may be distorted by confounding factors, such as stress or other laboratory conditions. Therefore, these results will not be used to develop tissue TRVs for the BERA.

Drevnick and Sandheinrich (2003) also investigated mercury toxicity in fathead minnows, focusing on multiple reproductive endpoints including spawning success. Exposure to dietary methyl mercury began 90-days post hatch and continued until sexual maturity, approximately 250 days. Three dose groups (0.06 as control; 0.87 as low treatment; and 3.93 mg/kg_{dw} as medium treatment) were evaluated to determine potential effects. As fish became sexually dimorphic, they were paired and placed in aquarium to monitor reproductive endpoints. Average carcass Hg concentrations were reported for males and females separately. Concentrations in the control group were 0.071 and 0.079 mg/kg_{ww} for males and females (respectively; average of 0.075 mg/kg_{ww}). Tissues concentrations in the low dose were 0.864 and 0.917 mg/kg_{ww} for males and females (respectively; average of 0.89 mg/kg_{ww}). Tissue concentrations in the medium dose were 3.557 and 3.842 mg/kg_{ww} for males and females (respectively; average of 3.7 mg/kg_{ww}).

No mortality was observed during the experiment that could be attributable to the mercury exposure. There were also no differences in wet weight or total length among treatment groups. Therefore, the NOAEL values for survival and growth is the maximum tissue concentration (3.7 mg/kg_{ww}).

Reproduction (spawning success, days to spawning, and relative fecundity of female fish)was significantly reduced in the low and medium dose groups compared to the control group. In addition, significant effects were reported for reproductive related endpoints including reproductive biomarkers, male testosterone and female estradiol levels, as well as adverse effects on gonad development in females. The authors also report significant negative relationships between male testosterone and female estradiol concentrations when regressed with total carcass Hg concentration. In a companion study, Drevnick et al. (2006) conducted a secondary analysis using the same test subjects reporting additional physiological effects to the ovaries of exposed female fish. However, as with Sandheinrich and Miller (2006), low rates of spawning in the control group (32%) call into question the validity of the reproductive endpoint in this study. Therefore, no reproduction TRV was derived from this study.

Hammerschmidt et al. (2002) evaluated spawning success, growth, and mortality of adult fathead minnow. This study examined effects associated with dietary exposure of methyl mercury for three treatment groups: 0.88, 4.11, and 8.46 mg/kg_{dw} methyl mercury. Fish were exposed either as juveniles until sexual maturity (phase 1), as adults during spawning (phase 2), or continuously throughout phase 1 and phase 2. For TRV derivations, only results from fish exposed continuously were considered. Fish exposed only during phase 1 had time to depurate before tissue residue concentrations were measured after spawning. Fish exposed only during phase 2 showed no reproductive toxicity despite high body burdens, which is contrary to the findings for continuously exposed and phase 1 exposed fish and suggests that juvenile development (phase 1) is a more sensitive exposure period.

Endpoints evaluated in this study included spawning success, days to spawn, hatching success, larval growth, and survival. Concentrations of total mercury in the carcass of parent fish were examined at the end of the exposure period after reproduction. No effects of methyl mercury treatment were found on fertilization success, hatching success, larval survival, growth, or mortality of adult fish. However, spawning success was significantly reduced in fish fed the same diets in both phases, with 75 percent of control fish spawning compared to 46, 50, and 36 percent for the low, medium, and high methyl mercury diets, respectively. In addition, days to spawning was delayed in continuously fed fish. Therefore, the lowest dietary test dose (0.88 mg/kg_{dw}) represents the low effect concentration for reproductive effects (spawning success), which corresponds to a tissue concentration of 0.778 mg/kg_{ww} (calculated from female mercury burdens and mean wet weight body weights reported by authors). The tissue NOAEL for survival and growth is the maximum concentration, corresponding to a female body burden of 5.68 mg/kg_{ww}.

Snarski and Olsen (1982) evaluated reproductive, survival and growth effects on fathead minnows exposed to control water on mercury chloride dissolved in water at one of five concentrations (0.26, 0.5, 1.02, 2.01, and 3.69 µg/L). Treatments were split into two different diets, dry trout starter and fresh *Artemia* (brine shrimp). The authors reported possible nutrient deficiencies in the dry trout starter based on the results of growth; therefore, only data from the

Artemia-fed exposure group were used in this assessment. Larval fathead minnows were exposed to aqueous mercury chloride for 60 days in flow-through systems. Carcass mercury concentrations were determined at the end of the 60-day exposure by sacrificing all but 15 fish from each treatment group. The 15 retained fish were randomly selected to continue for a secondary 41-week exposure. During the 60-day initial exposure, no mortality was observed in any mercury treatment group. However, significant reductions in body weight of larval/young fish were observed at carcass residue concentrations of 4.76 mg/kg_{ww}. Given that the initial exposure phase used larval fish these results will not be used to develop tissue TRVs for the BERA.

During the subsequent 41-week exposure, male and female fish were paired to measure the effects of spawning and growth/survival of offspring. The adult fish were sacrificed at the end of the 41-week exposure to determine carcass mercury concentrations. Tissue levels that corresponded to the five aqueous concentrations (0.26, 0.5, 1.02, 2.01, and 3.69 µg/L) were 1.36, 2.84, 4.47, 9.41 and 18.8 mg/kg_{ww}, respectively. The authors report significant reductions in spawning and growth of fish at residue concentrations of 4.47 and 1.36 mg/kg_{ww}, respectively. There were no effects on survival during the 41-week exposure. Therefore, the tissue NOAEL for survival is 18.8 mg/kg_{ww}. The tissue NOAEL and LOAEL values for reproduction (spawning) are 1.36 and 4.47 mg/kg_{ww} (respectively) and the tissue LOAEL for growth is 1.36 mg/kg_{ww}. A tissue NOAEL for growth cannot be calculated from this data.

Tatara et al. (2002) used sediment mesocosm exposures to measure the effects on growth (weight and length), fecundity and probability of female fish becoming gravid using mosquitofish. Additionally, the authors also measured changes in genetic composition of mosquitofish populations. Four replicates of a control and four replicates of mercury contaminated sediment mesocosms were evaluated for reproductive and genetic effects. The mercury concentrations in the sediment were not reported. There were no statistically significant differences between mercury treatment on standard length or weight for adult males and females. There were also no significant differences in sex ratio between treatment and control mesocosms. The average whole body effect concentration for growth (i.e., NOAEL) across the four replicates was 5.86 mg/kg_{ww}.

The authors concluded that mercury exposure as well as the sex ratio in the mesocosm influenced the total fecundity, with mercury exposed females having reduced fecundity (i.e., reduced total number of eggs and embryos relative to control). The average whole body effect concentration for these reproductive effects (i.e., LOAEL) across the four replicates was 5.86 mg/kg_{ww}.

McKim et al. (1976) measured the survival and long-term effects of aqueous methyl mercury chloride exposure on three generations of brook trout. Fish were exposed to six levels of aqueous methyl mercury: <0.01 (control), 0.03, 0.09, 0.29, 0.93, and 2.93 µg/L. Whole-body residue concentrations were reported by the authors for the first generation only, with second generation residues reported in a figure. Reduced survival was observed in the highest dose group of the first generation (88% mortality), with a corresponding average tissue residue of 23.5 mg/kg_{ww}. First generation exposure to 0.93 µg/L methyl mercury significantly reduced hatchability and juvenile weight compared to controls, although duplicates showed considerable variability (84% and 0% compared to 97% in both control groups). The corresponding average tissue residue for this group was 9.4 mg/kg_{ww}. First generation spawning success was not affected at any of the concentrations below the highest dose group. In the second generation, tissue residue concentrations of 9.5 mg/kg_{ww} and above were associated with complete spawning failure and reduced survival.

The first generation reproduction and growth LOAEL and NOAEL for this study are 9.4 mg/kg_{ww} and 3.4 mg/kg_{ww}, respectively. The first generation survival LOAEL and NOAEL are 23.5 mg/kg_{ww} and 9.4 mg/kg_{ww}, respectively. The second generation survival and reproduction NOAEL and LOAEL are 9.5 mg/kg_{ww} and 2 mg/kg_{ww}, respectively.

Rodgers and Beamish (1982) evaluated the potential effects on growth by measuring the weight gain of fingerling rainbow trout following exposure to four dietary treatments of methyl mercury in diet (<0.1 [control], 23.9, 46.9, and 94.8 mg/kg) for a period of 12 weeks. The authors also examined the effects of meal size under three treatment scenarios: *ad libitum*, 2 percent of fish wet weight per day, and 1 percent of fish wet weight per day. It is difficult to interpret effects attributable solely to mercury exposure in the restricted diets because it would be difficult to know based on the study reporting whether any growth effects, if present, result from dietary restrictions or the mercury content of the diet. Therefore, this assessment focuses on the use of the results on the unrestricted (*ad libitum*) diet scenario. Whole-body residue concentrations of mercury were analyzed at 0, 14, 28, 56, and 84 days by randomly sampling 5 fish from each treatment group tank. The authors report that residue concentrations stabilized after 56 to 85 days at 10, 20, and 30 mg/kg_{ww} in the low, medium, and high dose groups, respectively. Statistically significant differences in fish weight (relative to control) were reported for all mercury treatments. These results support an unbounded tissue-based LOAEL of 10 mg/kg_{ww} for growth.

Webber and Haines (2003) evaluated the effects of dietary exposures of methyl mercury on the survival, growth, predator avoidance behaviors, and brain acetylcholinesterase levels of golden shiners. Responses were reported for three mercury dietary treatment groups in the presence of a predator: 0.012 (control), 0.455, and 0.959 mg/kg_{ww}. Mean whole body tissue residues corresponding to the two treatment groups were 0.230 and 0.518 mg/kg_{ww}. There were no effects on growth or survival reported at the maximum tissue concentration. Behavioral effects were reported at the lower treatment group tissue level (0.23 mg/kg_{ww}) but this is difficult to extrapolate to an environmental settings based on the study design.

Stefansson et al. (2013) evaluated dietary mercury effects on growth and survival of a freshwater forage fish, inland silverside. Fish were exposed to control and four dietary concentrations of methylmercury (0.56, 3.33, 6.78 and 13.96 mg/kg) for 70 days. Diet, water, and residue concentrations were measured at 0, 23, 46, and 70 days in order to calculate bioaccumulation and growth rates. Significant effects on mortality occurred in the highest treatment group relative to controls throughout the 70 day exposure period. Whole body residues ranged up to 155 mg/kg_{dw} (approximately 31 mg/kg_{ww}, assuming fish moisture content of 80%) across the three diets. The authors reported tissue NOAEL and LOAEL values for survival of 7 and 31 mg/kg_{ww}. The tissue NOAEL and LOAEL for growth were 10 and 31 mg/kg_{ww}.

Stefansson et al. (2014) assessed fathead minnows exposed via diet to methyl mercury. Because the study was primarily intended to trace maternal transfer of methyl mercury, its assessment of reproduction was limited to egg production and did not include spawning, hatching, or offspring growth or survival. Fish were exposed to four dietary concentrations of methyl mercury: 0.04 (control), 1.04, 5.02, and 9.90 mg/kg dry weight. Each treatment group consisted of six replica tanks, and dosing occurred for 91 days. At the end of the experiment, total mercury was measured in fish carcasses.

Average egg production was 74, 49, 69, and 10 for the control, low, medium, and high dose groups, respectively. The low and medium dose groups did not differ statistically from the control. Unfortunately, water quality issues resulted in the loss of several replicate tanks at all levels, with only two tanks remaining in the high dose group. Therefore the high dose group was excluded from the author's statistical analysis used to assess spawning success. Nonetheless, the magnitude of the difference between the high dose groups and other groups suggests a toxicological effect. Regression analysis of individuals from all groups found a significant negative relationship between total mercury concentrations in eggs, which were significantly linked to maternal dietary exposures, and number of eggs produced. The high dose group, with a corresponding tissue residue value of 38 mg/kg_{dw} (estimated from figure; equivalent to 7.6 mg/kg_{ww}), was selected as the LOAEL from this study. The NOAEL tissue residue for this study, corresponding with the medium dose group, is 23 mg/kg_{dw} (estimated from figure; equivalent to 4.6 mg/kg_{ww}).

Liao et al. (2007) assessed survival and development in Japanese medaka. Fish were exposed to methyl mercury chloride in water at concentrations of 0 (control), 0.01, 0.1, 1 μg/L. Additional groups of fish were exposed to these concentrations of methyl mercury in combination with low, medium, and high concentrations of selenium. Results from concurrent mercury and selenium exposures were not included in the tissue TRV development because selenium is an antagonist for mercury toxicity and also may affect mercury bioaccumulation. Each treatment group comprised 80 fish, and fish were exposed for 210 days. Ten fish from each treatment group were sampled for whole tissue residue analysis on days 150 and 180.

Although the study authors reported reduced spawning in exposed fish, reproduction was not statistically evaluated. Fish exposed to methyl mercury only (i.e., without selenium) displayed

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a significant relationship between dose and mortality, with mortality rates of 15%, 25%, and 36.25% in the low, medium, and high dose groups, respectively, compared to 12.5% mortality in the control group. In addition, increased numbers of vertebral abnormalities were observed in fish exposed to methyl mercury only. The low dose group of fish exposed to mercury only was selected as the LOAEL from this study, with a corresponding mean whole body mercury concentration of 0.048 mg/kg_{ww}.

Penglase et al. (2014) assessed reproductive toxicity in zebrafish exposed to methyl mercury in combination with selenium using a 2x2 factorial design. Each exposure diet contained a combination of low and high levels of methyl mercury (0.05 and 12 mg/kg_{dw}) and selenium (0.7 and 10 mg/kg_{dw}). Low levels of selenium were considered sufficient to meet dietary requirements. Only results from fish fed low levels of selenium were considered for TRV derivations. Three fish per treatment group were sampled for tissue analysis after 50 days on treatment diets. Another twenty-seven female fish per treatment group were paired with undosed males for spawning at three time points during the experiment (78, 97, or 133 days on treatment diet). Growth, survival, mating success, and fecundity were monitored.

Average mercury concentrations in whole zebra fish were 33.31 mg/kg_{dw} (equivalent to t6.66 mg/kg_{ww}) in the treatment group fed high levels of mercury combined with low selenium, and 0.27 mg/kg_{dw} (equivalent to 0.054 mg/kg_{ww}) in the treatment group fed low levels of mercury and selenium. After 153 days on the treatment diet, fish exposed to high levels of mercury combined with low levels of selenium had 36% lower body weights and 26% decreased survival compared to the other three treatment groups. At the first spawning event (78 days on treatment diet), reproductive success (measured as embryos per female) was significantly higher for fish fed high levels of mercury combined with low levels of selenium compared to fish fed low levels of mercury and selenium. However, at the second spawning event (97 days on treatment diet) reproductive success did not differ for this group, and by the third spawning event (133 days on treatment diet), fish exposed to high levels of mercury combined with low levels of selenium had 37% lower rates of reproductive success and 49% lower rates of mating success compared to fish fed low levels of mercury and selenium. The average mercury body burden in high dose treatment groups (6.66 mg/kg_{ww}) was selected as the LOAEL based on this study.

Bridges et al. (2016) assessed reproduction in adult fathead minnows exposed for 30 days to dietary methyl mercury dry weight doses of 0.02 mg/kg (control), 0.87 mg/kg (low dose), and 5.5 mg/kg (high dose). After five days of exposure, each treatment group was assessed for frequency of spawning, clutch size, and total egg production. Twenty fertilized embryos from each clutch were collected and assessed for hatching rates. Mercury concentrations in muscles were measured for fifteen adult females and five adult males from each treatment group.

Average mercury concentrations in adult (male and female) muscles were 0.06 mg/kg_{ww} (control), 0.6 mg/kg_{ww} (low dose), and 3.21 mg/kg_{ww} (high dose). Embryo-larval mortality was found to be significantly higher for the high dose group compared to the low dose and control groups. Other reproductive endpoints (clutch size, egg output, spawning frequency) were not affected by dietary methyl mercury. The high dose group was selected as the tissue LOAEL (3.21 mg/kg_{ww}) and the low dose group was selected as the tissue NOAEL (0.6 mg/kg_{ww}).

<u>*Synopsis*</u>

The geometric means of the tissue TRV_{NOAEL} and TRV_{LOAEL} across all of these studies are 3.23 and 4.14 mg/kg_{ww}, respectively. For the ten bounded results, the geometric means of the TRV_{NOAEL} and TRV_{LOAEL} values are 3.20 and 10.7 mg/kg_{ww}.

4.2 FISH TISSUE BASED TRVS FOR TOTAL PCBS

Aroclors 1254 and 1260 were the two most commonly detected PCB mixtures in the sediments collected from the on-Site ponds in 2008 (Integral 2016)[12]. Although studies on either Aroclor mixture will be evaluated for deriving the TRVs for total PCBs, preference will be given to studies examining Aroclor 1254.

The studies used to develop the tissue TRVs for PCBs are presented in **Table 4-2**. For clarity the studies that were evaluated for the development of the TRV_{NOAEL} and TRV_{LOAEL} for PCBs in fish were segregated to whether they were reported in the ERED database or from other sources.

Summary of ERED Data Sources for TRV_{NOAEL}

There were eight studies reported in the ERED database that reported NOAEL values for whole body fish.

Duke et al. (1970) exposed field-collected juvenile pinfish (*Lagodon rhomboides*), an estuarine species, to three concentrations (1, 10 and 100 µg/L) of Aroclor 1254 in a static system. Fish exhibited no mortality after 24- or 48-hours of exposure. The average whole body tissue levels for the three exposure levels were 0.98, 3.8 and 17 mg/kg, respectively. The latter was reported as the NOAEL in the ERED database. Because an estuarine species was used in this study, it was not retained as a candidate to derive the TRVs for the freshwater fish for this site.

Lieb et al. (1974) fed juvenile rainbow trout (*Salmo gaidneri*) a diet containing 15 mg/kg of Aroclor 1254 for 32 weeks. All fish grew normally relative to controls, there was no mortality, and no apparent toxicity. The average whole body tissue level was 8 mg/kg at the end of the exposure period. The latter value was reported as the NOAEL in the ERED database.

[12] Forage fish samples were collected in May 2016 and the tissue levels for PCBs are not yet available.

Nestel and Budd (1975) fed rainbow trout (*Salmo gaidneri*) a control diet or diets containing 1, 10 or 100 mg/kg of Aroclor-1254 for up to 330 days. There were no impacts on growth rate in any of the fish with the PCB fortified diets. The whole body average total PCB concentrations in the fish fed diets with 1, 10 or 100 mg/kg were 1.4, 2.3 and 81.1 mg/kg (respectively). The latter value was reported as the NOAEL in the ERED database.

Mauck et al. (1978) exposed brook trout (*Salvelinus fontinalis*) eggs for 10 days and fry for 118 days to Aroclor 1254 in water. Water concentrations ranged from 0.43 to 13 µg/L Growth rates and skeletal development were monitored for post-hatch. There were no effects on growth or survival in trout with tissue levels of 31 and 71 mg/kg_{ww}, respectively. Both of these values were reported as NOAELs in the ERED database. There were growth and survival effects at tissue levels of 125 mg/kg_{ww}, which represented the LOAEL. Both endpoints were used for the TRV derivation.

Berlin et al. (1981) exposed lake trout (*Salvelinus namaycush*) sac fry to graded concentrations of Aroclor 1254 via food and water for 176 days. Resulting tissue concentrations ranged from 1.53 mg/kg_{ww} in the lowest concentration treatment group to 26.3 mg/kg_{ww} in the highest concentration treatment group. The latter value was reported as the NOAEL for growth in the ERED database, while the lower tissue level (1.53 mg/kg_{ww}) was reported as the LOAEL for survival.

Mac and Seelye (1981) exposed lake trout (*S. namaycush*) sac fry (a sensitive life stage) to a nominal concentration of 50 ng/L (50 ppt) of Aroclor 1254 in water for up to 48 days. The Lake Trout fry originated from a wild population. Fish were also fed during this period with a control diet (0.06 mg/kg PCBs) and PCB-spiked diet (0.72 mg/kg). Fish were sampled on days 4, 7, 10, 17, 32, and 48 and evaluated for whole body levels of PCBs. There was no apparent effect on growth throughout the exposure period. Cumulative mortality after 48 days was slightly higher for the exposed group (16.6%) compared to the control (12.5%). This difference was statistically significant, reflecting the study's large sample size (500 fish per treatment group), but does not indicate a biologically relevant effect. The tissue levels ranged from 5.0 to 7.3 mg/kg_{ww} for the exposed fish[13]. The latter represents the NOAEL from this study.

Bouraly and Millischer (1989) examined the uptake and elimination of a pentachlorobiphenyl mixture in the zebrafish (*Brachydanio rerio*) after waterborne exposure. Fish were exposed for 30 days to a nominal water concentration of 1 mg/L. No mortality was observed during this period. The whole body tissue concentration at the end of the study was 4,240 mg/kg (as reported in the ERED database). This study was not included for tissue TRV development since this is a tropical freshwater species and the test organisms were exposed to pentachlorobiphenyl mixture, rather than an Aroclor PCB mixture.

[13] The tissue levels reported in the ERED database do not match those reported in Mac and Seelye (1981). The latter were used for the TRV calculations presented herein.

Powell et al. (2003) measured growth in juvenile Chinook salmon exposed to Aroclor 1254 for 28 days at measured dietary doses of 0.051 mg/kg (control), 0.43 mg/kg, 1.1 mg/kg, 2.8 mg/kg, and 17.0 mg/kg. Body weights and fork length were measured for 20 individual fish in each treatment group at the start and end of the 28 day exposure. Aroclor 1254 body burden was measured in composite samples of 10 whole fish per treatment group at the conclusion of the 28 day exposure.

Aroclor 1254 body burdens ranged from below the detection limit for the control group to 0.95 mg/kg_{ww} for the high dose group. No effects on PCB treatment were observed on body weight and fork length. Therefore, the Aroclor 1254 body burden of the high dose group was selected as the no effect level (0.95 mg/kgww).

There was only one fish study available for Aroclor 1260 in the ERED database. This study (DeFoe et al., 1978) reported a NOED of 7,600 mg/kg_{lipid} of the fathead minnow (*Pimephales promelas*) embryos based on a waterborne exposure. This study was not considered to be adequate to develop a TRV specific to Aroclor 1260.

Other Literature Sources for the TRV_{NOAEL}

There were several additional references that were not in the ERED database but reported in the literature or used by state or federal agency ERAs. These have also been included in **Table 4-2.**

Hansen et al. (1973) exposed female sheepshead minnow (*Cyprinondon variegatus*) to Aroclor-1254 in water using a flow-through system. Fish were exposed for 28 days to control water or five nominal concentrations of Aroclor 1254 in water (0.1, 0.32, 1.0, 3.2 and 10 ug/L). All fish survived and egg production was induced. The eggs were fertilized and placed in PCB-free flowing seawater and observed for mortality. Survival of fry to one week of age was 77 percent for eggs from adults from the 0.32 μg/L concentration in water treatment (average 9.3 mg/kg in tissue of females), as compared to 95 percent survival of fry from control adults and 97 percent survival of fry from adults from the NOAEL treatment (0.1 μg/L; average 1.9 mg/kg in tissue of females). This study was used to derive the tissue-based TRV_{NOAEL} and TRV_{LOAEL} of 1.9 mg/kg and 9.3 mg/kg, respectively, for both the Hudson River Revised BERA (USEPA, 2000) and Onondaga Lake BERA (NYSDEC, 2002)[14].

Bengtsson (1980) assessed the effects of Clophen A50 on reproduction and growth in minnows. Treatment groups consisting of 32 minnows each were exposed to diets of 0, 20, 200, and 2000 mg/kg_{dw} for 40 days. Observation of fish continued for another 260 days (300 days total). Fish were sampled for PCB analysis at four time points during the study. Growth was assessed by measuring body weight of 12 fish per treatment group at day 46 and again at day 79.

[14] This paper was cited as "Hansen et al (1974)" in EPA (2000) and NYSDEC (2002) but the correct publication year was 1973.

Reproduction was assessed during spawning from days 235 to 300. Eggs were collected and assessed for hatchability.

PCBs (total Aroclor or congeners) concentration in whole body fish at day 171 (~ 2 months before spawning) were 0.2, 1.6, 15, and 170 mg/kg_{ww} for the control, low, medium, and high dose groups, respectively. A dose-dependent relationship between Clophen A50 dose and adult mortality was observed between day 235 and 300; however this endpoint was not evaluated statistically. Growth rates were significantly higher in the high dose group compared to the control group. Mean growth rates were also higher in the low and medium dose groups compared to the controls, but not significantly so. Hatchability was significantly reduced in the high dose group compared to the control. Hatching time was significantly reduced in the medium and high dose groups compared to the control, which the authors suggest resulted in an increased number of fry deaths. Therefore, the PCB body concentration of the medium dose group was selected as the LOAEL (15 mg/kg_{ww}). This study was used in the draft Hudson River BERA (USEPA, 1999b) to derive the TRV, but was not used for the Hudson River Revised BERA (USEPA, 2000).

Holm et al. (1993) assessed reproduction in three-spined sticklebacks fed low and high doses of Clophen A50 (doses were not reported). Dosing groups consisted of 20 females each. After 3.5 months of exposure, female fish were mated with unexposed males. Spawning success was measured as the number of females spawning within 24 hours of pairing. Eggs were collected and the number of fry and unhatched eggs were counted. After the reproduction period, two fish per dose group were analyzed for concentrations of Clophen A50 in carcasses.

Mean wet weight Clophen A50 concentrations in carcasses were 102 mg/kg for the low dose group, 289 mg/kg for the high dose group, and <1 mg/kg for the control group. Spawning success was reduced in the low dose group (25%) and in the high dose group (55%) compared to the control group (80%). Although Holm et al. (1993) reported that these values did not differ significantly, the large differences in spawning success among the treatment groups suggests the presence of a toxicological effect from PCB exposure. Therefore, the low dose group was selected as a LOAEL (102 mg/kg_{ww}). No difference was observed among treatment groups in number of eggs laid per gram female.

Hansen et al. (1971) assessed survival in juvenile pinfish and spot exposed to Aroclor 1254 through water. Spot we exposed to concentrations of 0, 1, and 5 µg/L Aroclor 1254 in a series of experiments that lasted 20 to 56 days. Pinfish were exposed to concentrations of 0 and 5 µg/L for 14 to 35 days. Whole body samples were analyzed for Aroclor 1254 for 10 fish per treatment group at selected intervals.

Only results from experiments that lasted over 27 days (chronic exposure) were considered for TRV derivation. Mortality was significantly greater in spots exposed to 5 µg/L Aroclor 1254 for 45 days (62% mortality) compared to controls (less than 7% mortality). Mortality in spots exposed to 1 μg/L Aroclor 1254 for 56 days did not differ from controls. The body burden of Aroclor 1254 in spot was 152 mg/kg_{ww} in the 5 ppb dose group and 27 mg/kg_{ww} in the 1 μg/L dose group, corresponding to the low effect and no effect levels, respectively. Whole body concentrations were not reported for control fish. Pinfish exposed to 5 μg/L Aroclor 1254 experienced higher rates of mortality (41%) compared to controls (less than 7%); however, it is unclear whether statistics were performed on these results, and therefore this receptor was excluded from TRV calculations.

NYSDEC (Newell et al., 1987) developed a fish tissue criterion for PCBs (0.11 mg/kg_{ww}) but this was for the assessment of potential impacts to piscivorous wildlife and not potential impacts to fish *per se*. Therefore, the NYSDEC value was not considered a candidate TRV for PCBs in fish, and was not included in **Table 4-2**.

Meador et al. (2002) derived a PCB residue effect threshold (RET) for the protection of juvenile salmonids (smolts) migrating through contaminated urban estuaries in the northwestern US. The authors included biomarker (e.g., biochemical changes), disease susceptibility, and growth and reproduction endpoints when they derived the RET of 2.4 $\mu g/g_{lipid}$. This is equivalent to 0.048 mg/Kg, assuming an average lipid content of 2%. This study was evaluated for the Housatonic River Ecological Risk Assessment (USEPA, 2003) but was not considered applicable to that ERA because biomarker effects were considered in the establishing the RET.

Broyles and Noveck (1979) exposed field-collected lake trout (*Salvelinus namaycush*) and Chinook salmon (*Oncorhynchus tshawytscha*) sac fry to water containing 5 μg/L of 2,4,5,2',4',5-hexachlorobiphenyl (PCB-153) for 15 days. Increased mortality was observed at a tissue level of 3.6 mg/kg_{ww} for this single congener. This study LOAEL was not included in the TRV development because it focused on a single PCB congener.

<u>*Synopsis*</u>

The geometric means of the TRV_{NOAEL} and TRV_{LOAEL} across all ten studies were 10.8 and 33.9 mg/kg_{ww}, respectively (**Table 4-2**). The TRV_{NOAEL} and TRV_{LOAEL} were 13.0 and 28.2 mg/kg_{ww} (respectively) from the five studies that reported bounded NOAEL and LOAEL values. Since preference is given to bounded study results, the latter TRV_{NOAEL} and TRV_{LOAEL} values will be used for BERA.

5 ASSESSMENT OF UNCERTAINTIES IN TRVS

Section 5.3 of the BERA Work Plan (Integral 2016) briefly discussed the uncertainty assessment that will be performed in the BERA Report, which includes an evaluation of the TRV development. Based on the preceding sections of this technical memorandum, the uncertainty assessment will include the following elements related to TRVs:

- Use of the TEL and PEL methods originally developed for deriving sediment benchmarks (CCME 1995 and MacDonald et al. 1996) as an alternative TRV derivation method for select COPECs and receptors.
- Evaluation of effects on the calculated risks of use of TRVs based on the individual DDE, DDD and DDT isomers rather than the aggregated TRV across all isomers for select receptors.
- Use of a single "all mammals" TRV for chromium for the assessment of small and large mammalian receptors in lieu of surrogate species for small or large mammalian receptors.
- Use of a single "all avians" TRV values for arsenic for the assessment of ducks and species other than ducks.
- An evaluation of the of effects on the calculated risks to great blue heron for use of a methyl mercury TRVs specific to wading birds rather than a TRV based on avian species other than ducks.

Additional evaluations of the TRVs may be performed as the BERA Report is developed.

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TABLES

Table 1-1a. Summary of the TRV_{NOAEL} and TRV_{LOAEL} Values for the Chemicals of Potential Ecological Concern and Mammalian Receptors to be Evaluated in the BERA
Rolling Knolls Landfill, Chatham, New Jersey

	Short-tailed Shrew		Meadow Vole		Little Brown Bat		Red Fox		Mink	
Chemical	TRV_{NOAEL} (mg/Kg-day)	TRV_{LOAEL} (mg/Kg-day)	TRV_{NOAEL} (mg/Kg-day)	TRV_{LOAEL} (mg/Kg-day)	TRV_{NOAEL} (mg/Kg-day)	TRV_{LOAEL} (mg/Kg-day)	TRV_{NOAEL} (mg/Kg-day)	TRV_{LOAEL} (mg/Kg-day)	TRV_{NOAEL} (mg/Kg-day)	TRV_{LOAEL} (mg/Kg-day)
Semivolatile Organics										
Bis(2-ethyl hexyl) phthalate	1.83E+01	1.83E+02	1.83E+01	1.83E+02	2.47E+01	2.47E+02	5.00E+00	5.00E+01	7.24E+00	7.24E+01
Butylbenzylphthalate	1.01E+02	5.05E+02	7.93E+01	3.97E+02	1.20E+02	6.01E+02	2.43E+01	1.21E+02	3.52E+01	1.76E+02
Pentachlorophenol	6.14E+01	2.47E+02	6.14E+01	2.47E+02	8.30E+01	3.34E+02	2.65E+00	1.07E+01	1.00E+00	NC
Benzo(a)anthracene	2.67E+00	1.14E+01	2.67E+00	1.14E+01	3.61E+00	1.54E+01	8.35E+00	2.18E+01	1.21E+01	3.15E+01
Benzo(a)pyrene	2.67E+00	1.14E+01	2.67E+00	1.14E+01	3.61E+00	1.54E+01	8.35E+00	2.18E+01	1.21E+01	3.15E+01
Chrysene	2.67E+00	1.14E+01	2.67E+00	1.14E+01	3.61E+00	1.54E+01	8.35E+00	2.18E+01	1.21E+01	3.15E+01
Dibenz(a,h)anthracene	2.67E+00	1.14E+01	2.67E+00	1.14E+01	3.61E+00	1.54E+01	8.35E+00	2.18E+01	1.21E+01	3.15E+01
Naphthalene	8.87E+01	2.45E+02	8.87E+01	2.45E+02	1.20E+02	3.31E+02	9.32E+01	2.64E+02	1.35E+02	3.83E+02
Pesticides										
2,4'-DDD	2.52E+01	5.27E+01	2.52E+01	5.27E+01	2.85E+01	8.12E+01	2.19E+00	7.19E+00	3.18E+00	1.04E+01
2,4'-DDE	2.52E+01	5.27E+01	2.52E+01	5.27E+01	2.85E+01	8.12E+01	2.19E+00	7.19E+00	3.18E+00	1.04E+01
2,4'-DDT	2.52E+01	5.27E+01	2.52E+01	5.27E+01	2.85E+01	8.12E+01	2.19E+00	7.19E+00	3.18E+00	1.04E+01
4,4'-DDE	2.52E+01	5.27E+01	2.52E+01	5.27E+01	2.85E+01	8.12E+01	2.19E+00	7.19E+00	3.18E+00	1.04E+01
4,4'-DDD	2.52E+01	5.27E+01	2.52E+01	5.27E+01	2.85E+01	8.12E+01	2.19E+00	7.19E+00	3.18E+00	1.04E+01
4,4'-DDT	2.52E+01	5.27E+01	2.52E+01	5.27E+01	2.85E+01	8.12E+01	2.19E+00	7.19E+00	3.18E+00	1.04E+01
Aldrin	1.01E+00	2.72E+00	1.01E+00	2.72E+00	1.36E+00	3.68E+00	5.05E-01	1.37E+00	7.32E-01	1.99E+00
alpha-Chlordane	4.58E+00	9.16E+00	4.58E+00	9.16E+00	6.19E+00	1.24E+01	1.25E+00	2.68E+00	1.81E+00	3.89E+00
beta-BHC	1.62E+01	NC	1.27E+01	NC	1.92E+01	NC	3.88E+00	NC	5.63E+00	NC
delta-BHC	1.62E+01	NC	1.27E+01	NC	1.92E+01	NC	3.88E+00	NC	5.63E+00	NC
Dieldrin	1.01E+00	2.72E+00	1.01E+00	2.72E+00	1.36E+00	3.68E+00	5.05E-01	1.37E+00	7.32E-01	1.99E+00
Endosulfan I	5.54E-01	NC	4.35E-01	NC	6.58E-01	NC	1.33E-01	NC	1.93E-01	NC
Endosulfan sulfate	5.54E-01	NC	4.35E-01	NC	6.58E-01	NC	1.33E-01	NC	1.93E-01	NC
Endrin	9.20E-02	9.20E-01	9.20E-02	9.20E-01	1.24E-01	1.24E+00	2.51E-02	2.51E-01	3.64E-02	3.64E-01
Endrin aldehyde	9.20E-02	9.20E-01	9.20E-02	9.20E-01	1.24E-01	1.24E+00	2.51E-02	2.51E-01	3.64E-02	3.64E-01
Endrin ketone	9.20E-02	9.20E-01	9.20E-02	9.20E-01	1.24E-01	1.24E+00	2.51E-02	2.51E-01	3.64E-02	3.64E-01
gamma-BHC (Lindane)	1.62E+01	NC	1.27E+01	NC	1.92E+01	NC	3.88E+00	NC	5.63E+00	NC
gamma-Chlordane	4.58E+00	9.16E+00	4.58E+00	9.16E+00	6.19E+00	1.24E+01	1.25E+00	2.68E+00	1.81E+00	3.89E+00
Heptachlor	5.92E+00	6.77E+00	4.65E+00	5.31E+00	7.04E+00	8.05E+00	1.42E+00	1.63E+00	1.00E-01	1.00E+00
Heptachlor epoxide	5.92E+00	6.77E+00	4.65E+00	5.31E+00	7.04E+00	8.05E+00	1.42E+00	1.63E+00	1.00E-01	1.00E+00
Aroclor PCBs										
Aroclor-1242	9.75E-01	1.90E+00	9.75E-01	1.90E+00	1.32E+00	2.56E+00	2.66E-01	5.17E-01	6.20E-02	2.29E-01
Aroclor-1248	9.75E-01	1.90E+00	9.75E-01	1.90E+00	1.32E+00	2.56E+00	2.66E-01	5.17E-01	6.20E-02	2.29E-01
Aroclor-1254	9.75E-01	1.90E+00	9.75E-01	1.90E+00	1.32E+00	2.56E+00	2.66E-01	5.17E-01	6.20E-02	2.29E-01
Aroclor-1260	9.75E-01	1.90E+00	9.75E-01	1.90E+00	1.32E+00	2.56E+00	2.66E-01	5.17E-01	6.20E-02	2.29E-01
Total PCBs	9.75E-01	1.90E+00	9.75E-01	1.90E+00	1.32E+00	2.56E+00	2.66E-01	5.17E-01	6.20E-02	2.29E-01
TEQs										
PCB-TEQ Congeners	9.84E-06	6.06E-05	7.72E-06	4.76E-05	1.17E-05	7.21E-05	2.36E-06	1.46E-05	2.43E-06	1.51E-05
PCDD/F-TEQ Congeners	9.84E-06	6.06E-05	7.72E-06	4.76E-05	1.17E-05	7.21E-05	2.36E-06	1.46E-05	2.43E-06	1.51E-05

Table 1-1a. Summary of the TRV_{NOAEL} and TRV_{LOAEL} Values for the Chemicals of Potential Ecological Concern and Mammalian Receptors to be Evaluated in the BERA
Rolling Knolls Landfill, Chatham, New Jersey

	Short-tailed Shrew		Meadow Vole		Little Brown Bat		Red Fox		Mink	
Chemical	TRV_{NOAEL} (mg/Kg-day)	TRV_{LOAEL} (mg/Kg-day)	TRV_{NOAEL} (mg/Kg-day)	TRV_{LOAEL} (mg/Kg-day)	TRV_{NOAEL} (mg/Kg-day)	TRV_{LOAEL} (mg/Kg-day)	TRV_{NOAEL} (mg/Kg-day)	TRV_{LOAEL} (mg/Kg-day)	TRV_{NOAEL} (mg/Kg-day)	TRV_{LOAEL} (mg/Kg-day)
Metals and Cyanide										
Antimony	1.85E+02	2.79E+02	1.85E+02	2.79E+02	2.50E+02	3.77E+02	2.79E-01	2.42E+00	4.04E-01	3.50E+00
Arsenic	1.01E+01	2.55E+01	1.01E+01	2.55E+01	1.36E+01	3.45E+01	3.87E+00	6.91E+00	5.60E+00	1.00E+01
Barium	1.65E+02	4.36E+02	1.65E+02	4.36E+02	2.23E+02	5.89E+02	4.45E+01	7.51E+01	6.46E+01	1.09E+02
Cadmium	4.21E+00	2.86E+01	4.21E+00	2.86E+01	5.69E+00	3.86E+01	8.25E-01	4.56E+00	1.20E+00	6.61E+00
Chromium	2.77E+00	1.61E+01	2.77E+00	1.61E+01	2.77E+00	1.61E+01	2.77E+00	1.61E+01	2.77E+00	1.61E+01
Cobalt	1.90E+01	3.30E+01	1.90E+01	3.30E+01	2.57E+01	4.46E+01	3.50E+00	6.51E+00	5.07E+00	9.43E+00
Copper	2.29E+02	4.99E+02	3.84E+02	8.38E+02	5.19E+02	1.13E+03	4.79E+01	9.02E+01	7.10E+00	1.38E+01
Lead	1.26E+02	4.51E+02	1.26E+02	4.51E+02	1.70E+02	6.09E+02	1.86E+01	5.49E+01	2.7E+01	8.0E+01
Manganese	1.59E+02	2.84E+02	1.59E+02	2.84E+02	2.15E+02	3.84E+02	4.59E+01	1.19E+02	6.66E+01	1.72E+02
Mercury, inorganic	1.32E+01	NC	1.32E+01	NC	1.78E+01	NC	3.60E+00	NC	1.00E+00	1.00E+01
Mercury, methyl	6.87E-02	3.43E-01	5.39E-02	2.70E-01	8.17E-02	4.08E-01	1.65E-02	8.25E-02	1.50E-02	2.50E-02
Nickel	2.05E+01	6.27E+01	2.05E+01	6.27E+01	2.77E+01	8.47E+01	3.02E+00	1.40E+01	4.37E+00	2.03E+01
Selenium	9.10E-01	2.00E+00	9.10E-01	2.00E+00	1.23E+00	2.70E+00	1.84E-01	3.64E-01	2.67E-01	5.28E-01
Silver	2.34E+02	2.79E+02	1.84E+02	2.19E+02	2.79E+02	3.31E+02	5.63E+01	6.70E+01	8.16E+01	9.70E+01
Vanadium	4.16E+00	8.31E+00	4.16E+00	8.31E+00	5.62E+00	1.12E+01	4.52E-01	4.42E+00	6.54E-01	6.41E+00
Zinc	5.61E+02	4.48E+03	5.61E+02	4.48E+03	7.58E+02	6.05E+03	1.04E+02	6.89E+02	1.60E+02	1.60E+03
Cyanide	2.88E+01	NC	2.88E+01	NC	3.89E+01	NC	8.54E+00	4.50E+01	1.24E+01	6.52E+01

Notes:

This table summarizes the TRV_{NOAEL} and TRV_{LOAEL} for the mammalian receptors. See Section 2 tables for derivation of these values.

NC = not calculated or not available

Table 1-1b. Summary of the TRV_{NOAEL} and TRV_{LOAEL} Values for the Chemicals of Potential Ecological Concern and Avian Receptors to be Evaluated in the BERA
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	American Robin TRV_{NOAEL} (mg/Kg-day)	American Robin TRV_{LOAEL} (mg/Kg-day)	Great blue heron TRV_{NOAEL} (mg/Kg-day)	Great blue heron TRV_{LOAEL} (mg/Kg-day)	Mallard Duck TRV_{NOAEL} (mg/Kg-day)	Mallard Duck TRV_{LOAEL} (mg/Kg-day)	Red-tailed hawk TRV_{NOAEL} (mg/Kg-day)	Red-tailed hawk TRV_{LOAEL} (mg/Kg-day)	Tree Swallow TRV_{NOAEL} (mg/Kg-day)	Tree Swallow TRV_{LOAEL} (mg/Kg-day)
Semivolatile Organics										
Bis(2-ethyl hexyl) phthalate	1.11E+00	NC	1.11E+00	NC	1.11E+00	NC	1.11E+00	NC	1.11E+00	NC
Butylbenzylphthalate	1.11E+00	NC	1.11E+00	NC	1.11E+00	NC	1.11E+00	NC	1.11E+00	NC
Pentachlorophenol	4.09E+01	9.29E+01	4.09E+01	9.29E+01	4.09E+01	9.29E+01	4.09E+01	9.29E+01	4.09E+01	9.29E+01
Benzo(a)anthracene	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00
Benzo(a)pyrene	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00
Chrysene	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00
Dibenz(a,h)anthracene	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00
Naphthalene	1.65E+02	1.65E+03	1.65E+02	1.65E+03	1.65E+02	1.65E+03	1.65E+02	1.65E+03	1.65E+02	1.65E+03
Pesticides										
2,4'-DDD	4.11E+00	1.46E+01	4.11E+00	1.46E+01	5.21E-01	3.40E+00	4.11E+00	1.46E+01	4.11E+00	1.46E+01
2,4'-DDE	4.11E+00	1.46E+01	4.11E+00	1.46E+01	5.21E-01	3.40E+00	4.11E+00	1.46E+01	4.11E+00	1.46E+01
2,4'-DDT	4.11E+00	1.46E+01	4.11E+00	1.46E+01	5.21E-01	3.40E+00	4.11E+00	1.46E+01	4.11E+00	1.46E+01
4,4'-DDE	4.11E+00	1.46E+01	4.11E+00	1.46E+01	5.21E-01	3.40E+00	4.11E+00	1.46E+01	4.11E+00	1.46E+01
4,4'-DDD	4.11E+00	1.46E+01	4.11E+00	1.46E+01	5.21E-01	3.40E+00	4.11E+00	1.46E+01	4.11E+00	1.46E+01
4,4'-DDT	4.11E+00	1.46E+01	4.11E+00	1.46E+01	5.21E-01	3.40E+00	4.11E+00	1.46E+01	4.11E+00	1.46E+01
Aldrin	7.52E-01	1.61E+00	7.52E-01	1.61E+00	2.36E-01	2.44E+00	7.52E-01	1.61E+00	7.52E-01	1.61E+00
alpha-Chlordane	2.14E+00	1.07E+01	2.14E+00	1.07E+01	2.14E+00	1.07E+01	2.14E+00	1.07E+01	2.14E+00	1.07E+01
beta-BHC	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00
delta-BHC	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00
Dieldrin	7.52E-01	1.61E+00	7.52E-01	1.61E+00	2.36E-01	2.44E+00	7.52E-01	1.61E+00	7.52E-01	1.61E+00
Endosulfan I	1.00E+01	1.00E+02	1.00E+01	1.00E+02	1.00E+01	1.00E+02	1.00E+01	1.00E+02	1.00E+01	1.00E+02
Endosulfan sulfate	1.00E+01	1.00E+02	1.00E+01	1.00E+02	1.00E+01	1.00E+02	1.00E+01	1.00E+02	1.00E+01	1.00E+02
Endrin	4.10E-02	1.90E-01	4.10E-02	1.90E-01	1.65E-01	3.00E-01	4.10E-02	1.90E-01	4.10E-02	1.90E-01
Endrin aldehyde	4.10E-02	1.90E-01	4.10E-02	1.90E-01	1.65E-01	3.00E-01	4.10E-02	1.90E-01	4.10E-02	1.90E-01
Endrin ketone	4.10E-02	1.90E-01	4.10E-02	1.90E-01	1.65E-01	3.00E-01	4.10E-02	1.90E-01	4.10E-02	1.90E-01
gamma-BHC (Lindane)	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00	2.00E-01	2.00E+00
gamma-Chlordane	2.14E+00	1.07E+01	2.14E+00	1.07E+01	2.14E+00	1.07E+01	2.14E+00	1.07E+01	2.14E+00	1.07E+01
Heptachlor	6.50E-02	6.50E-01	6.50E-02	6.50E-01	6.50E-02	6.50E-01	6.50E-02	6.50E-01	6.50E-02	6.50E-01
Heptachlor epoxide	6.50E-02	6.50E-01	6.50E-02	6.50E-01	6.50E-02	6.50E-01	6.50E-02	6.50E-01	6.50E-02	6.50E-01
Aroclor PCBs										
Aroclor-1242	3.16E-01	2.32E+00	3.16E-01	2.32E+00	7.00E+00	1.40E+01	3.16E-01	2.32E+00	3.16E-01	2.32E+00
Aroclor-1248	3.16E-01	2.32E+00	3.16E-01	2.32E+00	7.00E+00	1.40E+01	3.16E-01	2.32E+00	3.16E-01	2.32E+00
Aroclor-1254	3.16E-01	2.32E+00	3.16E-01	2.32E+00	7.00E+00	1.40E+01	3.16E-01	2.32E+00	3.16E-01	2.32E+00
Aroclor-1260	3.16E-01	2.32E+00	3.16E-01	2.32E+00	7.00E+00	1.40E+01	3.16E-01	2.32E+00	3.16E-01	2.32E+00
Total PCBs	3.16E-01	2.32E+00	3.16E-01	2.32E+00	7.00E+00	1.40E+01	3.16E-01	2.32E+00	3.16E-01	2.32E+00
TEQs										
PCB-TEQ Congeners	1.40E-05	1.40E-04	1.40E-05	1.40E-04	1.40E-05	1.40E-04	1.40E-05	1.40E-04	1.40E-05	1.40E-04
PCDD/F-TEQ Congeners	1.40E-05	1.40E-04	1.40E-05	1.40E-04	1.40E-05	1.40E-04	1.40E-05	1.40E-04	1.40E-05	1.40E-04

Table 1-1b. Summary of the TRV_{NOAEL} and TRV_{LOAEL} Values for the Chemicals of Potential Ecological Concern and Avian Receptors to be Evaluated in the BERA
Rolling Knolls Landfill, Chatham, New Jersey

	American Robin		Great blue heron		Mallard Duck		Red-tailed hawk		Tree Swallow	
Chemical	TRV_{NOAEL} (mg/Kg-day)	TRV_{LOAEL} (mg/Kg-day)	TRV_{NOAEL} (mg/Kg-day)	TRV_{LOAEL} (mg/Kg-day)	TRV_{NOAEL} (mg/Kg-day)	TRV_{LOAEL} (mg/Kg-day)	TRV_{NOAEL} (mg/Kg-day)	TRV_{LOAEL} (mg/Kg-day)	TRV_{NOAEL} (mg/Kg-day)	TRV_{LOAEL} (mg/Kg-day)
Metals and Cyanide										
Antimony	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Arsenic	3.70E+00	4.51E+00	3.70E+00	4.51E+00	3.70E+00	4.51E+00	3.70E+00	4.51E+00	3.70E+00	4.51E+00
Barium	2.08E+01	4.17E+01	2.08E+01	4.17E+01	2.08E+01	4.17E+01	2.08E+01	4.17E+01	2.08E+01	4.17E+01
Cadmium	2.03E+00	5.96E+00	2.03E+00	5.96E+00	3.08E+00	2.56E+01	2.03E+00	5.96E+00	2.03E+00	5.96E+00
Chromium	3.77E+01	7.54E+01	3.77E+01	7.54E+01	5.63E-01	2.81E+00	3.77E+01	7.54E+01	3.77E+01	7.54E+01
Cobalt	5.45E+00	1.11E+01	5.45E+00	1.11E+01	1.48E+01	1.48E+02	5.45E+00	1.11E+01	5.45E+00	1.11E+01
Copper	2.01E+01	3.60E+01	2.01E+01	3.60E+01	2.41E+01	7.50E+01	2.01E+01	3.60E+01	2.01E+01	3.60E+01
Lead	1.05E+01	5.38E+01	1.05E+01	5.38E+01	1.66E+01	8.50E+01	1.05E+01	5.38E+01	1.05E+01	5.38E+01
Manganese	2.57E+02	3.77E+02	2.57E+02	3.77E+02	2.57E+02	3.77E+02	2.57E+02	3.77E+02	2.57E+02	3.77E+02
Mercury, inorganic	4.50E-01	9.00E-01	4.50E-01	9.00E-01	4.50E-01	9.00E-01	4.50E-01	9.00E-01	4.50E-01	9.00E-01
Mercury, methyl	1.20E-01	1.56E-01	1.20E-01	1.56E-01	7.00E-02	4.02E-01	1.20E-01	1.56E-01	1.20E-01	1.56E-01
Nickel	1.61E+01	2.39E+01	1.61E+01	2.39E+01	1.07E+01	4.70E+01	1.61E+01	2.39E+01	1.61E+01	2.39E+01
Selenium	5.47E-01	1.21E+00	5.47E-01	1.21E+00	1.29E+00	3.31E+00	5.47E-01	1.21E+00	5.47E-01	1.21E+00
Silver	6.50E+00	6.50E+01	6.50E+00	6.50E+01	7.96E+00	1.99E+02	6.50E+00	6.50E+01	6.50E+00	6.50E+01
Vanadium	1.24E+00	2.55E+00	1.24E+00	2.55E+00	1.99E+01	1.99E+02	1.24E+00	2.55E+00	1.24E+00	2.55E+00
Zinc	1.00E+02	1.74E+02	1.00E+02	1.74E+02	1.01E+02	1.74E+02	1.00E+02	1.74E+02	1.00E+02	1.74E+02
Cyanide	1.40E-01	1.40E+00	1.40E-01	1.40E+00	1.40E-01	1.40E+00	1.40E-01	1.40E+00	1.40E-01	1.40E+00

Notes:
This table summarizes the TRV_{NOAEL} and TRV_{LOAEL} for the avian receptors. See Section 3 tables for derivation of these values.
NC = not calculated or not available

Table 1-1c. Summary of the Fish Tissue-Based TRV_{NOAEL} and TRV_{LOAEL} Values for the Bioaccumulative Chemicals of Potential Ecological Concern to be Evaluated in the BERA
Rolling Knolls Landfill, Chatham, New Jersey

	Fish	
Chemical	TRV_{NOAEL} (mg/Kg_{ww})	TRV_{LOAEL} (mg/Kg_{ww})
Aroclor PCBs		
Aroclor-1242	1.30E+01	2.82E+01
Aroclor-1248	1.30E+01	2.82E+01
Aroclor-1254	1.30E+01	2.82E+01
Aroclor-1260	1.30E+01	2.82E+01
Total PCBs	1.30E+01	2.82E+01
Metals		
Mercury, methyl	3.20E+00	1.07E+01

Notes:
This table summarizes the TRV_{NOAEL} and TRV_{LOAEL} for the bioacumulative COPECs in fish. See Section 4 tables for derivation of these values.

Table 2-1a. Data Sources Used to Develop Food-Chain Toxicity Reference Values for Small Mammals
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Selected TRV_{NOAEL} (mg/kg_{bw}-day)	Selected TRV_{LOAEL} (mg/kg_{bw}-day)	Source/Comments
Semivolatile Organics												
Bis(2-ethyl hexyl) phthalate	BEHP	Mice	105 days	Reproduction	Oral	Control or three test diets (10, 100 and 1,000 mg/kg)	NOAEL, LOAEL	10 mg/kg in diet	100 mg/kg in diet	1.83E+01	1.83E+02	Lamb et al (1987). TRVs calculated by Sample et al (1996).
Butyl benzyl phthalate	BBP	Rat	Multigeneration	Reproduction	Oral	Control or three test diets (750, 3,750, and 11,250 mg/kg`	NOAEL, LOAEL	750 mg/kg in diet	3,750 mg/kg in diet	5.00E+01	250	Tyl et al (2004). Value for small mammals body weight scaled from rat data.
Pentachlorophenol	Pentachlorophenol	Mouse	56 to 175 days	Growth, reproduction, survival	Oral	Multiple	NOAEL	27.8 to 122 mg/kg-d	---	6.14E+01	2.47E+02	USEPA (2007b), Unbounded values. TRV_{LOAEL} estimated from ratio of rat TRVs (see text).
Benzo(a)anthracene	Benzo(a)pyrene	guinea pig, mouse	9 to 385 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.615 to 10 mg/kg-d	3.01 to 40 mg/kg-d	2.67E+00	1.14E+01	USEPA (2007a), Evaluated as H-PAH.
Benzo(a)pyrene	Benzo(a)pyrene	guinea pig, mouse	9 to 385 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.615 to 10 mg/kg-d	3.01 to 40 mg/kg-d	2.67E+00	1.14E+01	USEPA (2007a), Evaluated as H-PAH.
Chrysene	Benzo(a)pyrene	guinea pig, mouse	9 to 385 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.615 to 10 mg/kg-d	3.01 to 40 mg/kg-d	2.67E+00	1.14E+01	USEPA (2007a), Evaluated as H-PAH.
Dibenz(a,h)anthracene	Benzo(a)pyrene	guinea pig, mouse	9 to 385 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.615 to 10 mg/kg-d	3.01 to 40 mg/kg-d	2.67E+00	1.14E+01	USEPA (2007a), Evaluated as H-PAH.
Naphthalene	Naphthalene	Mouse	8 to 567 days	Growth, survival	Oral	Multiple	NOAEL, LOAEL	52.7 to 250 mg/kg-d	100 to 500 mg/kg-d	8.87E+01	2.45E+02	USEPA (2007a), Evaluated as L-PAH.
Pesticides												
2,4'-DDD	DDT and metabolites	Mice, bat and hamster	8 to 504 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	12.7 to 48.3 mg/kg-d	25.4 to 96.5 mg/kg-d	2.52E+01	5.27E+01	USEPA (2007c); Separate TRVs also developed for bats (see text)
2,4'-DDE	DDT and metabolites	Mice, bat and hamster	8 to 504 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	12.7 to 48.3 mg/kg-d	25.4 to 96.5 mg/kg-d	2.52E+01	5.27E+01	USEPA (2007c); Separate TRVs also developed for bats (see text)
2,4'-DDT	DDT and metabolites	Mice, bat and hamster	8 to 504 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	12.7 to 48.3 mg/kg-d	25.4 to 96.5 mg/kg-d	2.52E+01	5.27E+01	USEPA (2007c); Separate TRVs also developed for bats (see text)
4,4'-DDE	DDT and metabolites	Mice, bat and hamster	8 to 504 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	12.7 to 48.3 mg/kg-d	25.4 to 96.5 mg/kg-d	2.52E+01	5.27E+01	USEPA (2007c); Separate TRVs also developed for bats (see text)
4,4'-DDD	DDT and metabolites	Mice, bat and hamster	8 to 504 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	12.7 to 48.3 mg/kg-d	25.4 to 96.5 mg/kg-d	2.52E+01	5.27E+01	USEPA (2007c); Separate TRVs also developed for bats (see text)
4,4'-DDT	DDT and metabolites	Mice, bat and hamster	8 to 504 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	12.7 to 48.3 mg/kg-d	25.4 to 96.5 mg/kg-d	2.52E+01	5.27E+01	USEPA (2007c); Separate TRVs also developed for bats (see text)
Aldrin	Dieldrin	Guinea pig, mouse	10 to 182 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.133 to 2.61 mg/kg-d	0.133 to 5.22 mg/kg-d	1.01E+00	2.72E+00	USEPA (2007d)
alpha-Chlordane	Chlordane	Mouse	6 generations	Reproduction	Oral	Three test doses: 25, 50, and 100 mg/kc	NOAEL, LOAEL	25 mg/kg	50 mg/kg	4.58E+00	9.16E+00	Sample et al (1996)
beta-BHC	gamma-BHC (Lindane)	Rat	3 generations	Repro	Oral	Control and 3 test dietary doses: 25, 50 and 100 mg/kg	NOAEL	100 mg/kg in diet	---	8.00E+00	---	Palmer et al. (1978). Value for rat is body-weight scaled to small mammals (Table 2-2b).
delta-BHC	gamma-BHC (Lindane)	Rat	3 generations	Repro	Oral	Control and 3 test dietary doses: 25, 50 and 100 mg/kg	NOAEL	100 mg/kg in diet	---	8.00E+00	---	Palmer et al. (1978). Value for rat is body-weight scaled to small mammals (Table 2-2b).
Dieldrin	Dieldrin	Guinea pig, mouse	10 to 182 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.133 to 2.61 mg/kg-d	0.133 to 5.22 mg/kg-d	1.01E+00	2.72E+00	USEPA (2007d)
Endosulfan I	Endosulfan	Rat	30 days	Repro	Oral	Control diet or three test diets (vareid by gender)	NOAEL	Max test doses 5 mg/kg-d (male) 1.5 mg/kg-d (female)	NA	2.74E-01	---	Dikshith et al. (1984). Value for rat is body-weight scaled to small mammals (Table 2-2b).
Endosulfan sulfate	Endosulfan	Rat	30 days	Repro	Oral	Control diet or three test diets (vareid by gender)	NOAEL	Max test doses 5 mg/kg-d (male) 1.5 mg/kg-d (female)	NA	2.74E-01	---	Dikshith et al. (1984). Value for rat is body-weight scaled to small mammals (Table 2-2b).
Endrin	Endrin	Mice	120 days	Reproduction, survival	Oral	Single dietary does: 5 mg/kg	LOAEL	NA	5 mg/kg in diet	9.20E-02	9.20E-01	Good and Ware (1969). Sample et al (1996) assumed TRV_{LOAEL} was ten times the TRV_{NOAEL}.
Endrin aldehyde	Endrin	Mice	120 days	Reproduction, survival	Oral	Single dietary does: 5 mg/kg	LOAEL	NA	5 mg/kg in diet	9.20E-02	9.20E-01	Good and Ware (1969). Sample et al (1996) assumed TRV_{LOAEL} was ten times the TRV_{NOAEL}.

Table 2-1a. Data Sources Used to Develop Food-Chain Toxicity Reference Values for Small Mammals
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Selected TRV_{NOAEL} (mg/kg_{bw}-day)	Selected TRV_{LOAEL} (mg/kg_{bw}-day)	Source/Comments
Endrin ketone	Endrin	Mice	120 days	Reproduction, survival	Oral	Single dietary does: 5 mg/kg	LOAEL	NA	5 mg/kg in diet	9.20E-02	9.20E-01	Good and Ware (1969). Sample et al (1996) assumed TRV_{LOAEL} was ten times the TRV_{NOAEL}.
gamma-BHC (Lindane)	gamma-BHC (Lindane)	Rat	3 generations	Repro	Oral	Control and 3 test dietary doses: 25, 50 and 100 mg/kg	NOAEL	100 mg/kg in diet	---	8.00E+00	---	Palmer et al. (1978). Value for rat is body-weight scaled to small mammals (Table 2-2b).
gamma-Chlordane	Chlordane	Mouse	6 generations	Reproduction	Oral	Three test doses: 25, 50, and 100 mg/kg	NOAEL, LOAEL	25 mg/kg	50 mg/kg	4.58E+00	9.16E+00	Sample et al (1996)
Heptachlor	NA	Rat	5 days	Growth, reproduction, survival	sc injection or oral gavage	Multiple	NOAEL, LOAEL	0.556 to 6 mg/kg-d	2.22 to 4.5 mg/kg-d	2.93E+00	3.35E+00	Kielhorn et al (2006) - rat data only, unbounded. See Table 2-4 for details. Value for rat is body weight-scaled to small mammals (Table 2-2b).
Heptachlor epoxide	NA	Rat	5 days	Growth, reproduction, survival	sc injection or oral gavage	Multiple	NOAEL, LOAEL	0.556 to 6 mg/kg-d	2.22 to 4.5 mg/kg-d	2.93E+00	3.35E+00	Kielhorn et al (2006) - rat data only, unbounded. See Table 2-4 for details. Value for rat is body weight-scaled to small mammals (Table 2-2b).
Aroclor PCBs												
Aroclor-1242	Aroclor 1254 or "environmental PCBs"	Mice	21 to 540 days	Growth, reproduction	Oral	Multiple	NOAEL, LOAEL	0.36 to 2.64 mg/kg-d	0.68 to 6.19 mg/kg-d	9.75E-01	1.90E+00	Values for all PCBs, unbounded data TRV values shown are the geometric means from multiple studies. See Table 2-6 for compilation.
Aroclor-1248	Aroclor 1254 or "environmental PCBs"	Mice	21 to 540 days	Growth, reproduction	Oral	Multiple	NOAEL, LOAEL	0.36 to 2.64 mg/kg-d	0.68 to 6.19 mg/kg-d	9.75E-01	1.90E+00	Values for all PCBs, unbounded data TRV values shown are the geometric means from multiple studies. See Table 2-6 for compilation.
Aroclor-1254	Aroclor 1254 or "environmental PCBs"	Mice	21 to 540 days	Growth, reproduction	Oral	Multiple	NOAEL, LOAEL	0.36 to 2.64 mg/kg-d	0.68 to 6.19 mg/kg-d	9.75E-01	1.90E+00	Values for all PCBs, unbounded data TRV values shown are the geometric means from multiple studies. See Table 2-6 for compilation.
Aroclor-1260	Aroclor 1254 or "environmental PCBs"	Mice	21 to 540 days	Growth, reproduction	Oral	Multiple	NOAEL, LOAEL	0.36 to 2.64 mg/kg-d	0.68 to 6.19 mg/kg-d	9.75E-01	1.90E+00	Values for all PCBs, unbounded data TRV values shown are the geometric means from multiple studies. See Table 2-6 for compilation.
Total PCBs	Aroclor 1254 or "environmental PCBs"	Mice	21 to 540 days	Growth, reproduction	Oral	Multiple	NOAEL, LOAEL	0.36 to 2.64 mg/kg-d	0.68 to 6.19 mg/kg-d	9.75E-01	1.90E+00	Values for all PCBs, unbounded data TRV values shown are the geometric means from multiple studies. See Table 2-6 for compilation.
TEQs												
PCB-TEQ Congeners	2,3,7,8-TCDD	Rat	Multigeneration	Growth, Survival, Reproduction	Oral in diet or gavage	Multiple	NOAEL, LOAEL	1.0E-6 to 5.43E-5 mg/kg-d	1.0E-5 to 2.17E-4 mg/kg-d	4.87E-06	3.00E-05	TRVs are geometric means of bounded data. See Table 2-8 for compilation. Values are body weight scaled to small mammals (Table 2-2b).
PCDD/F-TEQ Congeners	2,3,7,8-TCDD	Rat	Multigeneration	Growth, Survival, Reproduction	Oral in diet or gavage	Multiple	NOAEL, LOAEL	1.0E-6 to 5.43E-5 mg/kg-d	1.0E-5 to 2.17E-4 mg/kg-d	4.87E-06	3.00E-05	TRVs are geometric means of bounded data. See Table 2-8 for compilation. Values are body weight scaled to small mammals (Table 2-2b).
Metals and Cyanide												
Antimony	Multiple	Mouse	14 to 21 days	Growth, Survival, Reproduction	Oral	Multiple	NOAEL, LOAEL	106 to 557 mg/kg-day	161 to 835 mg/kg-day	1.85E+02	2.79E+02	USEPA (2005a).
Arsenic	Arsenic oxide, Arsenic trichloride	Mouse	9 to 42 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	2.84 to 24 mg/kg-day	5.69 to 48 mg/kg-day	1.01E+01	2.55E+01	USEPA (2005b).
Barium	Barium hydroxide	Mouse	13 to 92 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	165 mg./kg-d	436 mg/kg-d	1.65E+02	4.36E+02	USEPA (2005c)
Cadmium	Multiple	Mouse, vole	6 to 252 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	0.094 to 571 mg/kg-d	2.28 to 2,160 mg/kg-d	4.21E+00	2.86E+01	USEPA (2005d)
Chromium	Multiple	cattle, mouse, pig, and rat	32 to 332 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	0.00663 to 1,770 mg/kg-d	2.82 to 92.1 mg/kg-d	2.77E+00	1.61E+01	USEPA (2008), unbounded data. Values are applied to all mammals (see text).
Cobalt	Multiple	Mouse	35 days	Growth	Oral in diet	Multiple	NOAEL, LOAEL	19 mg./kg-d	33 mg/kg-d	1.90E+01	3.30E+01	USEPA (2005e). Values from single bounded study used.
Copper	Multiple	Mouse	8 to 92 days	Growth, survival	Oral in diet	Multiple	NOAEL, LOAEL	33.8 to 19,466 mg/kg-d	101 to 47,519 mg/kg-d	3.84E+02	8.38E+02	USEPA (2007e).
Lead	Multiple	Mouse	14 to 60 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	4 to 1,260 mg/kg-d	8 to 2,530 mg/kg-d	1.26E+02	4.51E+02	USEPA (2007f).
Manganese	Multiple	Hamster, mouse	4 to 100 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	125 to 270 mg/kg-d	284 mg/kg-d	1.59E+02	2.84E+02	USEPA (2007f), unbounded data.

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Table 2-1a. Data Sources Used to Develop Food-Chain Toxicity Reference Values for Small Mammals
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Selected TRV_{NOAEL} (mg/kg_{bw}-day)	Selected TRV_{LOAEL} (mg/kg_{bw}-day)	Source/Comments
Mercury, inorganic	Mercuric chloride	Mouse	20 months (240 days)	Growth, survival	Oral in diet	Multiple	NOAEL	13.2 mg/kg-d	NA	1.30E+00	NA	Revis et al. (1989).
Mercury, methyl	methyl mercury chloride	Rat	Three generations	Reproduction	Oral in diet	Three doses: 0.1, 0.5 and 2.5 mg/kg Hg in diet	NOAEL, LOAEL	0.5 mg/kg	0.5 mg/kg-d	3.40E-02	1.70E-01	Verschuuren et al (1976). TRVs calculated by Sample et al (1996).
Nickel	Multiple	Meadow vole, mouse	14 to 180 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	1.35 to 107 mg/kg-d	2.71 to 309 mg/kg-d	2.05E+01	6.27E+01	USEPA (2007g).
Selenium	Multiple	Hamster, mouse	8 to 329 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	0.072 to 10 mg/kg-d	0.0145 to 25.4 mg/kg-d	9.10E-01	2.00E+00	USEPA (2007h).
Silver	Silver acetate, silver nitrate	Rat	20 to 112 days	Growth, survival	Oral in diet	Multiple	NOAEL, LOAEL	116 mg/kg-d	80.2 to 188 mg/kg-day	1.16E+02	1.38E+02	USEPA (2006). Unbounded data.
Vanadium	Multiple	Mouse	9 to 12 days	Growth, survival	Oral in diet	Multiple	NOAEL, LOAEL	4.16 mg/kg-d	8.31 mg/kg-d	4.16E+00	8.31E+00	USEPA (2005g).
Zinc	Multiple	Mouse	21 to 91 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	458 to 1,419 mg/kg-d	2,838 to 4,927 mg/kg-d	5.61E+02	4.48E+03	USEPA (2007i).
Cyanide	Sodium Cyanide	Mice (female)	1 day	Lethality	Oral (water)	Control or five doses in drinking water (3, 10, 30, 100 or 300 mg/L).	NOAEL	300 mg/L	NA	2.88E+01	---	NTP (1993). No effects observed on male mice. Could not calculate TRV_{LOAEL} from this study.

Note:
Only the results from the bounded studies are shown, unless note
The test organisms shown are those that correspond to the TRVs

Table 2-1b. Data Sources Used to Develop Food-Chain Toxicity Reference Values for Rats
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Selected TRV_{NOAEL} (mg/kg_{bw}-day)	Selected TRV_{LOAEL} (mg/kg_{bw}-day)	Source/Comments
Semivolatile Organics												
Bis(2-ethyl hexyl) phthalate	BEHP	Mice	105 days	Reproduction	Oral	Control or three test diets (10, 100 and 1,000 mg/kg)	NOAEL, LOAEL	10 mg/kg in diet	100 mg/kg in diet	1.83E+01	1.83E+02	Lamb et al (1987). TRVs calculated by Sample et al (1996). Values for mice are bod weight scaled for other mammals (Tables 2-2a and 2-2b).
Butyl benzyl phthalate	BBP	Rat	Multigeneration	Reproduction	Oral	Control or three test diets (750, 3,750, and 11,250 mg/kg)	NOAEL, LOAEL	750 mg/kg in diet	3,750 mg/kg in diet	5.00E+01	2.50E+02	Tyl et al (2004).
Pentachlorophenol	Pentachlorophenol	Rat	10 to 240 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	2.36 to 14.7 mg/kg-d	9.45 to 42.6 mg/kg-d	5.45E+00	2.20E+01	USEPA (2007b)
Benzo(a)anthracene	Multiple H-PAHs	Rat	10 to 360 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	5 to 53.9 mg/kg-d	24 to 118 mg/kg-d	1.72E+01	4.48E+01	USEPA (2007a), Evaluated as H-PAH.
Benzo(a)pyrene	Multiple H-PAHs	Rat	10 to 360 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	5 to 53.9 mg/kg-d	24 to 118 mg/kg-d	1.72E+01	4.48E+01	USEPA (2007a), Evaluated as H-PAH.
Chrysene	Multiple H-PAHs	Rat	10 to 360 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	5 to 53.9 mg/kg-d	24 to 118 mg/kg-d	1.72E+01	4.48E+01	USEPA (2007a), Evaluated as H-PAH.
Dibenz(a,h)anthracene	Multiple H-PAHs	Rat	10 to 360 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	5 to 53.9 mg/kg-d	24 to 118 mg/kg-d	1.72E+01	4.48E+01	USEPA (2007a), Evaluated as H-PAH.
Naphthalene	Naphthalene	Rat	9 to 90 days	Growth, survival	Oral	Multiple	NOAEL, LOAEL	50 to 735 mg/kg-d	150 to 1,470 mg/kg-d	1.92E+02	5.44E+02	USEPA (2007a), Evaluated as L-PAH.
Pesticides												
2,4'-DDD	DDT and metabolites	Rat	5 to 360 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.11 to 90.3 mg/kg-d	0.274 to 137 mg/kg-d	4.52E+00	1.48E+01	USEPA (2007c); Separate TRVs also developed for mink.
2,4'-DDE	DDT and metabolites	Rat	5 to 360 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.11 to 90.3 mg/kg-d	0.274 to 137 mg/kg-d	4.52E+00	1.48E+01	USEPA (2007c); Separate TRVs also developed for mink.
2,4'-DDT	DDT and metabolites	Rat	5 to 360 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.11 to 90.3 mg/kg-d	0.274 to 137 mg/kg-d	4.52E+00	1.48E+01	USEPA (2007c); Separate TRVs also developed for mink.
4,4'-DDE	DDT and metabolites	Rat	5 to 360 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.11 to 90.3 mg/kg-d	0.274 to 137 mg/kg-d	4.52E+00	1.48E+01	USEPA (2007c); Separate TRVs also developed for mink.
4,4'-DDD	DDT and metabolites	Rat	5 to 360 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.11 to 90.3 mg/kg-d	0.274 to 137 mg/kg-d	4.52E+00	1.48E+01	USEPA (2007c); Separate TRVs also developed for mink.
4,4'-DDT	DDT and metabolites	Rat	5 to 360 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.11 to 90.3 mg/kg-d	0.274 to 137 mg/kg-d	4.52E+00	1.48E+01	USEPA (2007c); Separate TRVs also developed for mink.
Aldrin	Dieldrin	Rat	2 to 750 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.015 to 9.42 mg/kg-d	0.03 to 24.2 mg/kg-d	1.04E+00	2.83E+00	USEPA, 2007d
alpha-Chlordane	Chlordane	Rat	Up to 2 years	Growth, reproduction, survival	Oral	NA	NOAEL, LOAEL	0.65 to 10.2 mg/kg-d	1.5 to 20.4 mg/kg-d	2.57E+00	5.53E+00	Calculated from data provided in USACHPPM (2005). See Table 2-3.
beta-BHC	gamma-BHC (Lindane)	Rat	3 generations	Repro	Oral	Control and 3 test dietary doses: 25, 50 and 100 mg/kg	NOAEL	100 mg/kg in diet	---	8.00E+00	---	Palmer et al. (1978).
delta-BHC	gamma-BHC (Lindane)	Rat	3 generations	Repro	Oral	Control and 3 test dietary doses: 25, 50 and 100 mg/kg	NOAEL	100 mg/kg in diet	---	8.00E+00	---	Palmer et al. (1978).
Dieldrin	Dieldrin	Rat	2 to 750 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.015 to 9.42 mg/kg-d	0.03 to 24.2 mg/kg-d	1.04E+00	2.83E+00	USEPA, 2007d
Endosulfan I	Endosulfan	Rat	30 days	Repro	Oral	Control diet or three test diets (vareid by gender)	NOAEL	Max test doses 5 mg/kg-d (male) 1.5 mg/kg-d (female)	NA	2.74E-01	---	Dikshith et al. (1984).
Endosulfan sulfate	Endosulfan	Rat	30 days	Repro	Oral	Control diet or three test diets (vareid by gender)	NOAEL	Max test doses 5 mg/kg-d (male) 1.5 mg/kg-d (female)	NA	2.74E-01	---	Dikshith et al. (1984).
Endrin	Endrin	Mice	120 days	Reproduction, survival	Oral	Single dietary doses: 5 mg/kg	LOAEL	NA	5 mg/kg in diet	9.20E-02	9.20E-01	Good and Ware (1969). Sample et al (1996) assumed TRV_{LOAEL} was ten times the TRV_{NOAEL}. These TRVs were body weight scaled for other mammals (Tables 2-2a and 2-2b).

Table 2-1b. Data Sources Used to Develop Food-Chain Toxicity Reference Values for Rats
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Selected TRV_{NOAEL} (mg/kg_{bw}-day)	Selected TRV_{LOAEL} (mg/kg_{bw}-day)	Source/Comments
Endrin aldehyde	Endrin	Mice	120 days	Reproduction, survival	Oral	Single dietary doses: 5 mg/kg	LOAEL	NA	5 mg/kg in diet	9.20E-02	9.20E-01	Good and Ware (1969). Sample et al (1996) assumed TRV_{LOAEL} was ten times the TRV_{NOAEL}. These TRVs were body weight scaled for other mammals (Tables 2-2a and 2-2b).
Endrin ketone	Endrin	Mice	120 days	Reproduction, survival	Oral	Single dietary doses: 5 mg/kg	LOAEL	NA	5 mg/kg in diet	9.20E-02	9.20E-01	Good and Ware (1969). Sample et al (1996) assumed TRV_{LOAEL} was ten times the TRV_{NOAEL}. These TRVs were body weight scaled for other mammals (Tables 2-2a and 2-2b).
gamma-BHC (Lindane)	gamma-BHC (Lindane)	Rat	3 generations	Repro	Oral	Control and 3 test dietary doses: 25, 50 and 100 mg/kg	NOAEL	100 mg/kg in diet	---	8.00E+00	---	Palmer et al. (1978).
gamma-Chlordane	Chlordane	Rat	Up to 2 years	Growth, reproduction, survival	Oral	NA	NOAEL, LOAEL	0.65 to 10.2 mg/kg-d	1.5 to 20.4 mg/kg-d	2.57E+00	5.53E+00	Calculated from data provided in USACHPPM (2005). See Table 2-3.
Heptachlor	NA	Rat	5 days	Growth, reproduction, survival	sc injection or oral gavage	Multiple	NOAEL, LOAEL	0.556 to 6 mg/kg-d	2.22 to 4.5 mg/kg-d	2.93E+00	3.35E+00	Kielhorn et al (2006) - rat data only, unbounded. See Table 2-4 for details.
Heptachlor epoxide	NA	Rat	5 days	Growth, reproduction, survival	sc injection or oral gavage	Multiple	NOAEL, LOAEL	0.556 to 6 mg/kg-d	2.22 to 4.5 mg/kg-d	2.93E+00	3.35E+00	Kielhorn et al (2006) - rat data only, unbounded. See Table 2-4 for details.
Aroclor PCBs												
Aroclor-1242	Aroclor 1254 or "environmental PCBs"	Mice	21 to 540 days	Growth, reproduction	Oral	Multiple	NOAEL, LOAEL	0.36 to 2.64 mg/kg-d	0.68 to 6.19 mg/kg-d	9.75E-01	1.90E+00	Values for all PCBs, unbounded data TRV values shown are the geometric means from multiple studies. See Table 2-6 for compilation. Values are body weight scaled for large mammals (Table 2-2a) except for mink.
Aroclor-1248	Aroclor 1254 or "environmental PCBs"	Mice	21 to 540 days	Growth, reproduction	Oral	Multiple	NOAEL, LOAEL	0.36 to 2.64 mg/kg-d	0.68 to 6.19 mg/kg-d	9.75E-01	1.90E+00	Values for all PCBs, unbounded data TRV values shown are the geometric means from multiple studies. See Table 2-6 for compilation. Values are body weight scaled for large mammals (Table 2-2a) except for mink.
Aroclor-1254	Aroclor 1254 or "environmental PCBs"	Mice	21 to 540 days	Growth, reproduction	Oral	Multiple	NOAEL, LOAEL	0.36 to 2.64 mg/kg-d	0.68 to 6.19 mg/kg-d	9.75E-01	1.90E+00	Values for all PCBs, unbounded data TRV values shown are the geometric means from multiple studies. See Table 2-6 for compilation. Values are body weight scaled for large mammals (Table 2-2a) except for mink.
Aroclor-1260	Aroclor 1254 or "environmental PCBs"	Mice	21 to 540 days	Growth, reproduction	Oral	Multiple	NOAEL, LOAEL	0.36 to 2.64 mg/kg-d	0.68 to 6.19 mg/kg-d	9.75E-01	1.90E+00	Values for all PCBs, unbounded data TRV values shown are the geometric means from multiple studies. See Table 2-6 for compilation. Values are body weight scaled for large mammals (Table 2-2a) except for mink.
Total PCBs	Aroclor 1254 or "environmental PCBs"	Mice	21 to 540 days	Growth, reproduction	Oral	Multiple	NOAEL, LOAEL	0.36 to 2.64 mg/kg-d	0.68 to 6.19 mg/kg-d	9.75E-01	1.90E+00	Values for all PCBs, unbounded data TRV values shown are the geometric means from multiple studies. See Table 2-6 for compilation. Values are body weight scaled for large mammals (Table 2-2a) except for mink.
TEQs												
PCB-TEQ Congeners	2,3,7,8-TCDD	Rat	Multigeneration	Growth, Survival, Reproduction	Oral in diet or gavage	Multiple	NOAEL, LOAEL	1.0E-6 to 5.43E-5 mg/kg-d	1.0E-5 to 2.17E-4 mg/kg-d	4.87E-06	3.00E-05	TRVs are geometric means of bounded data. See Table 2-8 for compilation.
PCDD/F-TEQ Congeners	2,3,7,8-TCDD	Rat	Multigeneration	Growth, Survival, Reproduction	Oral in diet or gavage	Multiple	NOAEL, LOAEL	1.0E-6 to 5.43E-5 mg/kg-d	1.0E-5 to 2.17E-4 mg/kg-d	4.87E-06	3.00E-05	TRVs are geometric means of bounded data. See Table 2-8 for compilation.
Metals and Cyanide												
Antimony	Multiple	Rat	31 to 91 days	Growth, Survival, Reproduction	Oral	Multiple	NOAEL, LOAEL	0.059 to 5.6 mg/kg-day	0.59 to 42 mg/kg-day	5.74E-01	4.98E+00	USEPA (2005a).
Arsenic	Multiple	Rat	2 to 546 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	4.43 to 10.3 mg/kg-day	7.5 to 20.6 mg/kg-day	7.97E+00	1.42E+01	USEPA (2005b).
Barium	Barium hydroxide	Rat	10 to 92 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	61 to 138 mg./kg-d	121 to 198 mg/kg-d	9.18E+01	1.55E+02	USEPA (2005c)
Cadmium	Multiple	Rat	4 to 720 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	0.1 to 50 mg/kg-d	1 to 75 mg/kg-d	1.70E+00	9.40E+00	USEPA (2005d)
Chromium	Multiple	cattle, mouse, pig, and rat	32 to 332 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	0.00663 to 1,770 mg/kg-d	2.82 to 92.1 mg/kg-d	2.77E+00	1.61E+01	USEPA (2008), unbounded data. Values are applied to all mammals (see text).

Table 2-1b. Data Sources Used to Develop Food-Chain Toxicity Reference Values for Rats
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Selected TRV_{NOAEL} (mg/kg_{bw}-day)	Selected TRV_{LOAEL} (mg/kg_{bw}-day)	Source/Comments
Cobalt	Multiple	Rat	28 to 69 days	Growth, survival	Oral in diet	Multiple	NOAEL, LOAEL	5 to 5.45 mg/kg-d	10.9 to 20 mg/kg-d	7.20E+00	1.34E+01	USEPA (2005e). Unbounded data
Copper	Multiple	Rat	7 to 92 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	17.2 to 812 mg/kg-d	35 to 1,738 mg/kg-d	9.86E+01	1.86E+02	USEPA (2007e).
Lead	Multiple	Rat	2 to 644 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	0.71 to 2,000 mg/kg-d	5 to 2,400 mg/kg-d	3.83E+01	1.13E+02	USEPA (2007c).
Manganese	Multiple	Rat	5 to 30 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	21 to 1,069 mg/kg-d	71 to 2,139 mg/kg-d	9.46E+01	2.45E+02	USEPA (2007f),
Mercury, inorganic	Mercuric chloride	Mouse	20 months (240 days)	Growth, survival	Oral in diet	Multiple	NOAEL	13.2 mg/kg-d	NA	1.32E+01	NA	Revis et al. (1989). Values are body weight-scaled to larger mammals (except mink).
Mercury, methyl	methyl mercury chloride	Rat	Three generations	Reproduction	Oral in diet	Three doses: 0.1, 0.5 and 2.5 mg/kg Hg in diet	NOAEL, LOAEL	0.5 mg/kg	0.5 mg/kg-d	3.40E-02	1.70E-01	Verschuuren et al (1976). TRVs calculated by Sample et al (1996).
Nickel	Multiple	Rat	21 to 118 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	1.1 to 164 mg/kg-d	3.31 to 327 mg/kg-d	6.21E+00	2.88E+01	USEPA (2007g).
Selenium	Multiple	Rat	7 to 240 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	0.053 to 0.996 mg/kg-d	0.265 to 1.81 mg/kg-d	3.80E-01	7.50E-01	USEPA (2007h).
Silver	Multiple	Rat	20 to 112 days	Growth, survival	Oral in diet	Multiple	NOAEL, LOAEL	116 mg/kg-d	80.2 to 188 mg/kg-day	1.16E+02	1.38E+02	USEPA (2006). Unbounded data.
Vanadium	Multiple	Rat	21 to 70 days	Growth, survival	Oral in diet	Multiple	NOAEL, LOAEL	0.022 to 9.6 mg/kg-d	5.11 to 17.9 mg/kg-d	9.30E-01	9.11E+00	USEPA (2005g).
Zinc	Multiple	Rat	14 to 91 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	181 to 234 mg/kg-d	452 to 2,514 mg/kg-d	2.15E+02	1.42E+03	USEPA (2007i).
Cyanide	Sodium Cyanide	Rats	Multiple	Growth, reproduction, survival	Oral (water and food)	Multiple	NOAEL, LOAEL	17.6 mg/kg-d	92.7 mg/kg-d	1.76E+01	9.27E+01	Geometric means of two studies, summarized in Table 2-9.

Note:
Only the results from the bounded studies are shown, unless noted.

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Table 2-2a. Supporting Calculations for Body Weight Scaling from Rat or Mouse Toxicity Data to Red Fox and Mink Food-Chain TRV_{NOAEL} and TRV_{LOAEL} Values
Rolling Knolls Landfill, Chatham, New Jersey

	Test Organism				Red Fox TRVs			Mink TRVs			
Chemical	TRV_{NOAEL} in test organism (mg/Kg-day)	TRV_{LOAEL} in test organism (mg/Kg-day)	Test Organism	Test Organism Body Weight (Kg)	Red Fox Body Weight (Kg)	Red Fox TRV_{NOAEL} (mg/Kg-day)	Red Fox TRV_{LOAEL} (mg/Kg-day)	Mink Body Weight (Kg)	Mink TRV_{NOAEL} (mg/Kg-day)	Mink $TRVL_{OAEL}$ (mg/Kg-day)	Comments
Semivolatile Organics											
Bis(2-ethyl hexyl) phthalate	1.83E+01	1.83E+02	Mouse	2.50E-02	4.5E+00	5.00E+00	5.00E+01	1.02E+00	7.24E+00	7.24E+01	
Butylbenzylphthalate	5.00E+01	2.50E+02	Rat	2.50E-01	4.5E+00	2.43E+01	1.21E+02	1.02E+00	3.52E+01	1.76E+02	
Pentachlorophenol	5.45E+00	2.20E+01	Rat	2.50E-01	4.5E+00	2.65E+00	1.07E+01	1.02E+00	1.00E+00	NC	Mink-specific TRV_{NOAEL} was available (see text for discussion). TRV_{LOAEL} was not available from EcoSSL document.
Benzo(a)anthracene	1.72E+01	4.48E+01	Rat	2.50E-01	4.5E+00	8.35E+00	2.18E+01	1.02E+00	1.21E+01	3.15E+01	Evaluated as an H-PAH
Benzo(a)pyrene	1.72E+01	4.48E+01	Rat	2.50E-01	4.5E+00	8.35E+00	2.18E+01	1.02E+00	1.21E+01	3.15E+01	Evaluated as an H-PAH
Chrysene	1.72E+01	4.48E+01	Rat	2.50E-01	4.5E+00	8.35E+00	2.18E+01	1.02E+00	1.21E+01	3.15E+01	Evaluated as an H-PAH
Dibenz(a,h)anthracene	1.72E+01	4.48E+01	Rat	2.50E-01	4.5E+00	8.35E+00	2.18E+01	1.02E+00	1.21E+01	3.15E+01	Evaluated as an H-PAH
Naphthalene	1.92E+02	5.44E+02	Rat	2.50E-01	4.5E+00	9.32E+01	2.64E+02	1.02E+00	1.35E+02	3.83E+02	Evaluated as an L-PAH
Pesticides											
2,4'-DDD	4.52E+00	1.48E+01	Rat	2.50E-01	4.5E+00	2.19E+00	7.19E+00	1.02E+00	3.18E+00	1.04E+01	
2,4'-DDE	4.52E+00	1.48E+01	Rat	2.50E-01	4.5E+00	2.19E+00	7.19E+00	1.02E+00	3.18E+00	1.04E+01	
2,4'-DDT	4.52E+00	1.48E+01	Rat	2.50E-01	4.5E+00	2.19E+00	7.19E+00	1.02E+00	3.18E+00	1.04E+01	
4,4'-DDE	4.52E+00	1.48E+01	Rat	2.50E-01	4.5E+00	2.19E+00	7.19E+00	1.02E+00	3.18E+00	1.04E+01	
4,4'-DDD	4.52E+00	1.48E+01	Rat	2.50E-01	4.5E+00	2.19E+00	7.19E+00	1.02E+00	3.18E+00	1.04E+01	
4,4'-DDT	4.52E+00	1.48E+01	Rat	2.50E-01	4.5E+00	2.19E+00	7.19E+00	1.02E+00	3.18E+00	1.04E+01	
Aldrin	1.04E+00	2.83E+00	Rat	2.50E-01	4.5E+00	5.05E-01	1.37E+00	1.02E+00	7.32E-01	1.99E+00	
alpha-Chlordane	2.57E+00	5.53E+00	Rat	2.50E-01	4.5E+00	1.25E+00	2.68E+00	1.02E+00	1.81E+00	3.89E+00	
beta-BHC	8.00E+00	NC	Rat	2.50E-01	4.5E+00	3.88E+00	NC	1.02E+00	5.63E+00	NC	TRV_{LOAEL} value was not available.
delta-BHC	8.00E+00	NC	Rat	2.50E-01	4.5E+00	3.88E+00	NC	1.02E+00	5.63E+00	NC	TRV_{LOAEL} value was not available.
Dieldrin	1.04E+00	2.83E+00	Rat	2.50E-01	4.5E+00	5.05E-01	1.37E+00	1.02E+00	7.32E-01	1.99E+00	
Endosulfan I	2.74E-01	NC	Rat	2.50E-01	4.5E+00	1.33E-01	NC	1.02E+00	1.93E-01	NC	TRV_{LOAEL} value was not available.
Endosulfan sulfate	2.74E-01	NC	Rat	2.50E-01	4.5E+00	1.33E-01	NC	1.02E+00	1.93E-01	NC	TRV_{LOAEL} value was not available.
Endrin	9.20E-02	9.20E-01	Mouse	2.50E-02	4.5E+00	2.51E-02	2.51E-01	1.02E+00	3.64E-02	3.64E-01	
Endrin aldehyde	9.20E-02	9.20E-01	Mouse	2.50E-02	4.5E+00	2.51E-02	2.51E-01	1.02E+00	3.64E-02	3.64E-01	
Endrin ketone	9.20E-02	9.20E-01	Mouse	2.50E-02	4.5E+00	2.51E-02	2.51E-01	1.02E+00	3.64E-02	3.64E-01	
gamma-BHC (Lindane)	8.00E+00	NC	Rat	2.50E-01	4.5E+00	3.88E+00	NC	1.02E+00	5.63E+00	NC	TRV_{LOAEL} value was not available.
gamma-Chlordane	2.57E+00	5.53E+00	Rat	2.50E-01	4.5E+00	1.25E+00	2.68E+00	1.02E+00	1.81E+00	3.89E+00	
Heptachlor	2.93E+00	3.35E+00	Rat	2.50E-01	4.5E+00	1.42E+00	1.63E+00	1.02E+00	1.00E-01	1.00E+00	Mink-specific TRVs were derived.
Heptachlor epoxide	2.93E+00	3.35E+00	Rat	2.50E-01	4.5E+00	1.42E+00	1.63E+00	1.02E+00	1.00E-01	1.00E+00	Mink-specific TRVs were derived.
Aroclor PCBs											
Aroclor-1242	9.75E-01	1.90E+00	Mouse	2.50E-02	4.5E+00	2.66E-01	5.17E-01	1.02E+00	6.20E-02	2.29E-01	Mink-specific TRVs were derived.
Aroclor-1248	9.75E-01	1.90E+00	Mouse	2.50E-02	4.5E+00	2.66E-01	5.17E-01	1.02E+00	6.20E-02	2.29E-01	Mink-specific TRVs were derived.
Aroclor-1254	9.75E-01	1.90E+00	Mouse	2.50E-02	4.5E+00	2.66E-01	5.17E-01	1.02E+00	6.20E-02	2.29E-01	Mink-specific TRVs were derived.
Aroclor-1260	9.75E-01	1.90E+00	Mouse	2.50E-02	4.5E+00	2.66E-01	5.17E-01	1.02E+00	6.20E-02	2.29E-01	Mink-specific TRVs were derived.
Total PCBs	9.75E-01	1.90E+00	Mouse	2.50E-02	4.5E+00	2.66E-01	5.17E-01	1.02E+00	6.20E-02	2.29E-01	Mink-specific TRVs were derived.
TEQs											
PCB-TEQ Congeners	4.87E-06	3.00E-05	Rat	2.50E-01	4.5E+00	2.36E-06	1.46E-05	1.02E+00	2.43E-06	1.51E-05	Mink-specific TRVs were derived.
PCDD/F-TEQ Congeners	4.87E-06	3.00E-05	Rat	2.50E-01	4.5E+00	2.36E-06	1.46E-05	1.02E+00	2.43E-06	1.51E-05	Mink-specific TRVs were derived.

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Table 2-2a. Supporting Calculations for Body Weight Scaling from Rat or Mouse Toxicity Data to Red Fox and Mink Food-Chain TRV_{NOAEL} and TRV_{LOAEL} Values
Rolling Knolls Landfill, Chatham, New Jersey

	Test Organism				Red Fox TRVs			Mink TRVs			
Chemical	TRV_{NOAEL} in test organism (mg/Kg-day)	TRV_{LOAEL} in test organism (mg/Kg-day)	Test Organism	Test Organism Body Weight (Kg)	Red Fox Body Weight (Kg)	Red Fox TRV_{NOAEL} (mg/Kg-day)	Red Fox TRV_{LOAEL} (mg/Kg-day)	Mink Body Weight (Kg)	Mink TRV_{NOAEL} (mg/Kg-day)	Mink $TRVL_{OAEL}$ (mg/Kg-day)	Comments
Metals and Cyanide											
Antimony	5.74E-01	4.98E+00	Rat	2.50E-01	4.5E+00	2.79E-01	2.42E+00	1.02E+00	4.04E-01	3.50E+00	
Arsenic	7.97E+00	1.42E+01	Rat	2.50E-01	4.5E+00	3.87E+00	6.91E+00	1.02E+00	5.60E+00	1.00E+01	
Barium	9.18E+01	1.55E+02	Rat	2.50E-01	4.5E+00	4.45E+01	7.51E+01	1.02E+00	6.46E+01	1.09E+02	
Cadmium	1.70E+00	9.40E+00	Rat	2.50E-01	4.5E+00	8.25E-01	4.56E+00	1.02E+00	1.20E+00	6.61E+00	
Chromium	---	---	---	---	NR	2.77E+00	1.61E+01	NR	2.77E+00	1.61E+01	TRVs across all mammals were calculated.
Cobalt	7.20E+00	1.34E+01	Rat	2.50E-01	4.5E+00	3.50E+00	6.51E+00	1.02E+00	5.07E+00	9.43E+00	
Copper	9.86E+01	1.86E+02	Rat	2.50E-01	4.5E+00	4.79E+01	9.02E+01	NR	7.10E+00	1.38E+01	Mink-specific TRVs were derived.
Lead	3.83E+01	1.13E+02	Rat	2.50E-01	4.5E+00	1.86E+01	5.49E+01	1.02E+00	2.69E+01	7.96E+01	
Manganese	9.46E+01	2.45E+02	Rat	2.50E-01	4.5E+00	4.59E+01	1.19E+02	1.02E+00	6.66E+01	1.72E+02	
Mercury, inorganic	1.32E+01	NC	Mouse	2.50E-02	4.5E+00	3.60E+00	NC	NR	1.00E+00	1.00E+01	Mink-specific TRVs were derived.
Mercury, methyl	3.40E-02	1.70E-01	Rat	2.50E-01	4.5E+00	1.65E-02	8.25E-02	NR	1.50E-02	2.50E-02	Mink-specific TRVs were derived.
Nickel	6.21E+00	2.88E+01	Rat	2.50E-01	4.5E+00	3.02E+00	1.40E+01	1.02E+00	4.37E+00	2.03E+01	
Selenium	3.80E-01	7.50E-01	Rat	2.50E-01	4.5E+00	1.84E-01	3.64E-01	1.02E+00	2.67E-01	5.28E-01	
Silver	1.16E+02	1.38E+02	Rat	2.50E-01	4.5E+00	5.63E+01	6.70E+01	1.02E+00	8.16E+01	9.70E+01	
Vanadium	9.30E-01	9.11E+00	Rat	2.50E-01	4.5E+00	4.52E-01	4.42E+00	1.02E+00	6.54E-01	6.41E+00	
Zinc	2.15E+02	1.42E+03	Rat	2.50E-01	4.5E+00	1.04E+02	6.89E+02	NR	1.60E+02	1.60E+03	Mink-specific TRVs were derived.
Cyanide	1.76E+01	9.27E+01	Rat	2.50E-01	4.5E+00	8.54E+00	4.50E+01	1.02E+00	1.24E+01	6.52E+01	

Notes:
This table summarizes the derivation of TRV_{NOAEL} and TRV_{LOAEL} for the mammalian receptors based on the values derived for the test organisms shown in Table 2-1a or 2-1b.
A 3/4-power body weight scaling factor was used for these calculations.
The receptor body weights are the same as those used in the BERA Work Plan (Integral 2016). The test organism body weights are from USEPA (1988).
NC = not calculated or not available

Table 2-2b. Supporting Calculations for Body Weight Scaling from Rat Toxicity Data to Small Mammal Food-Chain TRV$_{NOAEL}$ and TRV$_{LOAEL}$ Values
Rolling Knolls Landfill, Chatham, New Jersey

	Test Organism				Short-tailed Shrew TRVs			Meadow Vole TRVs			Little Brown Bat TRVs			
Chemical	TRV$_{NOAEL}$ in test organism (mg/Kg-day)	TRV$_{LOAEL}$ in test organism (mg/Kg-day)	Test Organism	Test Organism Body Weight (Kg)	Shrew Body Weight (Kg)	Shrew TRV$_{NOAEL}$ (mg/Kg-day)	Shrew TRV$_{LOAEL}$ (mg/Kg-day)	Vole Body Weight (Kg)	Vole TRV$_{NOAEL}$ (mg/Kg-day)	Vole TRV$_{LOAEL}$ (mg/Kg-day)	Bat Body Weight (Kg)	Bat TRV$_{NOAEL}$ (mg/Kg-day)	Bat TRVL$_{OAEL}$ (mg/Kg-day)	Comments
Semivolatile Organics														
Bis(2-ethyl hexyl) phthalate	1.83E+01	1.83E+02	Mouse	2.50E-02	---	1.83E+01	1.83E+02	---	1.83E+01	1.83E+02	7.50E-03	2.47E+01	2.47E+02	
Butylbenzylphthalate	5.00E+01	2.50E+02	Rat	2.50E-01	1.5E-02	1.01E+02	5.05E+02	3.95E-02	7.93E+01	3.97E+02	7.50E-03	1.20E+02	6.01E+02	
Pentachlorophenol	6.14E+01	2.47E+02	Mouse	2.50E-02	---	6.14E+01	2.47E+02	---	6.14E+01	2.47E+02	7.50E-03	8.30E+01	3.34E+02	
Benzo(a)anthracene	2.67E+00	1.14E+01	Mix	2.50E-02	---	2.67E+00	1.14E+01	---	2.67E+00	1.14E+01	7.50E-03	3.61E+00	1.54E+01	Evaluated as an H-PAH
Benzo(a)pyrene	2.67E+00	1.14E+01	Mix	2.50E-02	---	2.67E+00	1.14E+01	---	2.67E+00	1.14E+01	7.50E-03	3.61E+00	1.54E+01	Evaluated as an H-PAH
Chrysene	2.67E+00	1.14E+01	Mix	2.50E-02	---	2.67E+00	1.14E+01	---	2.67E+00	1.14E+01	7.50E-03	3.61E+00	1.54E+01	Evaluated as an H-PAH
Dibenz(a,h)anthracene	2.67E+00	1.14E+01	Mix	2.50E-02	---	2.67E+00	1.14E+01	---	2.67E+00	1.14E+01	7.50E-03	3.61E+00	1.54E+01	Evaluated as an H-PAH
Naphthalene	8.87E+01	2.45E+02	Mouse	2.50E-02	---	8.87E+01	2.45E+02	---	8.87E+01	2.45E+02	7.50E-03	1.20E+02	3.31E+02	Evaluated as L-PAH.
Pesticides														
2,4'-DDD	2.52E+01	5.27E+01	Mix	2.50E-02	---	2.52E+01	5.27E+01	---	2.52E+01	5.27E+01	---	2.85E+01	8.12E+01	TRVs for shrews and voles same as test organism. Bat-specific TRVs were derived
2,4'-DDE	2.52E+01	5.27E+01	Mix	2.50E-02	---	2.52E+01	5.27E+01	---	2.52E+01	5.27E+01	---	2.85E+01	8.12E+01	TRVs for shrews and voles same as test organism. Bat-specific TRVs were derived
2,4'-DDT	2.52E+01	5.27E+01	Mix	2.50E-02	---	2.52E+01	5.27E+01	---	2.52E+01	5.27E+01	---	2.85E+01	8.12E+01	TRVs for shrews and voles same as test organism. Bat-specific TRVs were derived
4,4'-DDE	2.52E+01	5.27E+01	Mix	2.50E-02	---	2.52E+01	5.27E+01	---	2.52E+01	5.27E+01	---	2.85E+01	8.12E+01	TRVs for shrews and voles same as test organism. Bat-specific TRVs were derived
4,4'-DDD	2.52E+01	5.27E+01	Mix	2.50E-02	---	2.52E+01	5.27E+01	---	2.52E+01	5.27E+01	---	2.85E+01	8.12E+01	TRVs for shrews and voles same as test organism. Bat-specific TRVs were derived
4,4'-DDT	2.52E+01	5.27E+01	Mix	2.50E-02	---	2.52E+01	5.27E+01	---	2.52E+01	5.27E+01	---	2.85E+01	8.12E+01	TRVs for shrews and voles same as test organism. Bat-specific TRVs were derived
Aldrin	1.01E+00	2.72E+00	Mix	2.50E-02	---	1.01E+00	2.72E+00	---	1.01E+00	2.72E+00	7.50E-03	1.36E+00	3.68E+00	
alpha-Chlordane	4.58E+00	9.16E+00	Mouse	2.50E-02	---	4.58E+00	9.16E+00	---	4.58E+00	9.16E+00	7.50E-03	6.19E+00	1.24E+01	
beta-BHC	8.00E+00	NC	Rat	2.50E-01	1.5E-02	1.62E+01	NC	3.95E-02	1.27E+01	NC	7.50E-03	1.92E+01	NC	TRV$_{LOAEL}$ value was not available.
delta-BHC	8.00E+00	NC	Rat	2.50E-01	1.5E-02	1.62E+01	NC	3.95E-02	1.27E+01	NC	7.50E-03	1.92E+01	NC	TRV$_{LOAEL}$ value was not available.
Dieldrin	1.01E+00	2.72E+00	Mix	2.50E-02	---	1.01E+00	2.72E+00	---	1.01E+00	2.72E+00	7.50E-03	1.36E+00	3.68E+00	
Endosulfan I	2.74E-01	NC	Rat	2.50E-01	1.5E-02	5.54E-01	NC	3.95E-02	4.35E-01	NC	7.50E-03	6.58E-01	NC	TRV$_{LOAEL}$ value was not available.
Endosulfan sulfate	2.74E-01	NC	Rat	2.50E-01	1.5E-02	5.54E-01	NC	3.95E-02	4.35E-01	NC	7.50E-03	6.58E-01	NC	TRV$_{LOAEL}$ value was not available.
Endrin	9.20E-02	9.20E-01	Mouse	2.50E-02	---	9.20E-02	9.20E-01	---	9.20E-02	9.20E-01	7.50E-03	1.24E-01	1.24E+00	
Endrin aldehyde	9.20E-02	9.20E-01	Mouse	2.50E-02	---	9.20E-02	9.20E-01	---	9.20E-02	9.20E-01	7.50E-03	1.24E-01	1.24E+00	
Endrin ketone	9.20E-02	9.20E-01	Mouse	2.50E-02	---	9.20E-02	9.20E-01	---	9.20E-02	9.20E-01	7.50E-03	1.24E-01	1.24E+00	
gamma-BHC (Lindane)	8.00E+00	NC	Rat	2.50E-01	1.5E-02	1.62E+01	NC	3.95E-02	1.27E+01	NC	7.50E-03	1.92E+01	NC	TRV$_{LOAEL}$ value was not available.
gamma-Chlordane	4.58E+00	9.16E+00	Mouse	2.50E-02	---	4.58E+00	9.16E+00	---	4.58E+00	9.16E+00	7.50E-03	6.19E+00	1.24E+01	
Heptachlor	2.93E+00	3.35E+00	Rat	2.50E-01	1.5E-02	5.92E+00	6.77E+00	3.95E-02	4.65E+00	5.31E+00	7.50E-03	7.04E+00	8.05E+00	
Heptachlor epoxide	2.93E+00	3.35E+00	Rat	2.50E-01	1.5E-02	5.92E+00	6.77E+00	3.95E-02	4.65E+00	5.31E+00	7.50E-03	7.04E+00	8.05E+00	
Aroclor PCBs														
Aroclor-1242	9.75E-01	1.90E+00	Mouse	2.50E-02	---	9.75E-01	1.90E+00	---	9.75E-01	1.90E+00	7.50E-03	1.32E+00	2.56E+00	
Aroclor-1248	9.75E-01	1.90E+00	Mouse	2.50E-02	---	9.75E-01	1.90E+00	---	9.75E-01	1.90E+00	7.50E-03	1.32E+00	2.56E+00	
Aroclor-1254	9.75E-01	1.90E+00	Mouse	2.50E-02	---	9.75E-01	1.90E+00	---	9.75E-01	1.90E+00	7.50E-03	1.32E+00	2.56E+00	
Aroclor-1260	9.75E-01	1.90E+00	Mouse	2.50E-02	---	9.75E-01	1.90E+00	---	9.75E-01	1.90E+00	7.50E-03	1.32E+00	2.56E+00	
Total PCBs	9.75E-01	1.90E+00	Mouse	2.50E-02	---	9.75E-01	1.90E+00	---	9.75E-01	1.90E+00	7.50E-03	1.32E+00	2.56E+00	
TEQs														
PCB-TEQ Congeners	4.87E-06	3.00E-05	Rat	2.50E-01	1.5E-02	9.84E-06	6.06E-05	3.95E-02	7.72E-06	4.76E-05	7.50E-03	1.17E-05	7.21E-05	
PCDD/F-TEQ Congeners	4.87E-06	3.00E-05	Rat	2.50E-01	1.5E-02	9.84E-06	6.06E-05	3.95E-02	7.72E-06	4.76E-05	7.50E-03	1.17E-05	7.21E-05	

Table 2-2b. Supporting Calculations for Body Weight Scaling from Rat Toxicity Data to Small Mammal Food-Chain TRV_{NOAEL} and TRV_{LOAEL} Values
Rolling Knolls Landfill, Chatham, New Jersey

	Test Organism				Short-tailed Shrew TRVs			Meadow Vole TRVs			Little Brown Bat TRVs			
Chemical	TRV_{NOAEL} in test organism (mg/Kg-day)	TRV_{LOAEL} in test organism (mg/Kg-day)	Test Organism	Test Organism Body Weight (Kg)	Shrew Body Weight (Kg)	Shrew TRV_{NOAEL} (mg/Kg-day)	Shrew TRV_{LOAEL} (mg/Kg-day)	Vole Body Weight (Kg)	Vole TRV_{NOAEL} (mg/Kg-day)	Vole TRV_{LOAEL} (mg/Kg-day)	Bat Body Weight (Kg)	Bat TRV_{NOAEL} (mg/Kg-day)	Bat $TRVL_{OAEL}$ (mg/Kg-day)	Comments
Metals and Cyanide														
Antimony	1.85E+02	2.79E+02	Mix	2.50E-02	---	1.85E+02	2.79E+02	---	1.85E+02	2.79E+02	7.50E-03	2.50E+02	3.77E+02	
Arsenic	1.01E+01	2.55E+01	Mix	2.50E-02	---	1.01E+01	2.55E+01	---	1.01E+01	2.55E+01	7.50E-03	1.36E+01	3.45E+01	
Barium	1.65E+02	4.36E+02	Mix	2.50E-02	---	1.65E+02	4.36E+02	---	1.65E+02	4.36E+02	7.50E-03	2.23E+02	5.89E+02	
Cadmium	4.21E+00	2.86E+01	Mix	2.50E-02	---	4.21E+00	2.86E+01	---	4.21E+00	2.86E+01	7.50E-03	5.69E+00	3.86E+01	
Chromium	---	---	---	---	---	2.77E+00	1.61E+01	---	2.77E+00	1.61E+01	---	2.77E+00	1.61E+01	TRVs across all mammals were calculated.
Cobalt	1.90E+01	3.30E+01	Mix	2.50E-02	---	1.90E+01	3.30E+01	---	1.90E+01	3.30E+01	7.50E-03	2.57E+01	4.46E+01	
Copper	3.84E+02	8.38E+02	Mix	2.50E-02	---	2.29E+02	4.99E+02	---	3.84E+02	8.38E+02	7.50E-03	5.19E+02	1.13E+03	TRVs for shrew were available (see text).
Lead	1.26E+02	4.51E+02	Mix	2.50E-02	---	1.26E+02	4.51E+02	---	1.26E+02	4.51E+02	7.50E-03	1.70E+02	6.09E+02	
Manganese	1.59E+02	2.84E+02	Mix	2.50E-02	---	1.59E+02	2.84E+02	---	1.59E+02	2.84E+02	7.50E-03	2.15E+02	3.84E+02	
Mercury, inorganic	1.32E+01	NC	Mouse	2.50E-02	---	1.32E+01	NC	---	1.32E+01	NC	7.50E-03	1.78E+01	NC	
Mercury, methyl	3.40E-02	1.70E-01	Rat	2.50E-01	1.5E-02	6.87E-02	3.43E-01	3.95E-02	5.39E-02	2.70E-01	7.50E-03	8.17E-02	4.08E-01	
Nickel	2.05E+01	6.27E+01	Mix	2.50E-02	---	2.05E+01	6.27E+01	---	2.05E+01	6.27E+01	7.50E-03	2.77E+01	8.47E+01	
Selenium	9.10E-01	2.00E+00	Mix	2.50E-02	---	9.10E-01	2.00E+00	---	9.10E-01	2.00E+00	7.50E-03	1.23E+00	2.70E+00	
Silver	1.16E+02	1.38E+02	Rat	2.50E-01	1.5E-02	2.34E+02	2.79E+02	3.95E-02	1.84E+02	2.19E+02	7.50E-03	2.79E+02	3.31E+02	
Vanadium	4.16E+00	8.31E+00	Mix	2.50E-02	---	4.16E+00	8.31E+00	---	4.16E+00	8.31E+00	7.50E-03	5.62E+00	1.12E+01	
Zinc	5.61E+02	4.48E+03	Mix	2.50E-02	---	5.61E+02	4.48E+03	---	5.61E+02	4.48E+03	7.50E-03	7.58E+02	6.05E+03	
Cyanide	2.88E+01	NC	Mouse	2.50E-02	---	2.88E+01	NC	---	2.88E+01	NC	7.50E-03	3.89E+01	NC	

Notes:
This table summarizes the derivation of TRV_{NOAEL} and TRV_{LOAEL} for the mammalian receptors based on the values derived for the test organisms shown in Table 2-1a or 2-1b.
TRVs based on mouse or a test species mix were used for short-tailed shrew and meadow vole. These values were boy weight-scaled for the little brown bat.
A 3/4-power body weight scaling factor was used for these calculations.
The test species "mix" refers to a mixture of small mammals (e.g., Guinea pig and mouse)
The receptor body weights are the same as those used in the BERA Work Plan (Integral 2016). The test organism body weights are from USEPA (1988).
NC = not calculated or not available
A dash indicates value is not required.

Table 2-3. Data Sources Used to Develop Rat Toxicity Reference Values for Chlordane
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Test Organism	Study Duration	Exposure Route	Dosage	Endpoints	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Ingestion Rate (g_{food}/day)	Body Weight (kg)	TRV_{NOAEL} (mg/kg-day)	TRV_{LOAEL} (mg/kg-day)	Same TRV used in Work Plan?	Source/Comments
Chlordane	Osborne-Mendel Rats	2 years	NR	NR	Growth (F0), Survival (F0, F1), Reproduction	NOAEL, LOAEL	NR	NR	NR	NR	6.50E-01	1.50E+00		Ingle (1952)
Chlordane	Osborne-Mendel Rats	2 years	NR	NR	Growth	NOAEL, LOAEL	NR	NR	NR	NR	1.02E+01	2.04E+01		NCI (1977)
Chlordane	F334 Rats	GD 6 to 19	NR	NR	Growth (F1); Survival (F1)	LOAEL	NR	NR	NR	NR	NR	2.10E+01		Narotsky and Kavlock (1995)
									All Results	Minimum	6.50E-01	1.50E+00		
										Maximum	1.02E+01	2.10E+01		
										Average	5.43E+00	1.43E+01		
										Geomean	2.57E+00	8.63E+00		
										N	2	3		
									Bounded Results	Minimum	6.50E-01	1.50E+00		
										Maximum	1.02E+01	2.04E+01		
										Average	5.43E+00	1.10E+01		
										Geomean	2.57E+00	5.53E+00		
										N	2	2		

Notes:
Summarized from USACHPPM (2005).
TRVs generated using rat data are body weight-scaled to all of the evaluated mammalian receptors.
GD = gestation days (sensitive exposure period)
NA = not available
NR = not reported in USACHPPM (2005)

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Table 2-4. Data Sources Used to Develop Rat Toxicity Reference Values for Heptachlor
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Test Organism	Study Duration	Exposure Route	Dosage	Endpoints	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Ingestion Rate (g_{food}/day)	Body Weight (kg)	TRV_{NOAEL} (mg/kg-day)	TRV_{LOAEL} (mg/kg-day)	Source/Comments
Heptachlor	Sprague-Dawley Rats (males)	2 weeks	sc injection	Control and 5 doses: 5, 10, 15, 20, 25 mg/kg_{bw}; Alternate days	Growth	NOAEL	---	25 mg/kg_{bw} (alternate days)	NA	NA	3.57E+00	NA	Wango et al. (1997); some testicular abnormalities noted at maximum dose.
Heptachlor	Sprague-Dawley Rats (females)	18 days	sc injection	Control and 2 doses: 5 and 20 mg/kg_{bw}; Alternate days	Reproduction	NOAEL, LOAEL	5 mg/kg_{bw} (alternate days)	20 mg/kg_{bw} (alternate days)	NA	NA	5.56E-01	2.22E+00	Oduma et al 1995a
Heptachlor	Sprague-Dawley Rats (females)	F0: 19 d; F1: 42 d	Oral gavage	Control and 3 doses: 0.03, 0.3 or 3 mg/kg-d	Reproduction (F0); Survival (F1)	NOAEL	3 mg/kg_{bw}-d	NA	NA	NA	3.00E+00	NA	Smialowicz et al (2001)
Heptachlor	Fischer-344 Rats (females)	F0: 13 d; F1: 21 d	Oral gavage	Control and 2 doses: 4.5 or 6 mg/kg-d	Growth (F0)	LOAEL	4.5 mg/kg-d	NA	NA	NA	NA	4.50E+00	Narotsky et al (1995)
					Survival (F1)	NOAEL	NA	6 mg/kg-d	NA	NA	6.00E+00	NA	
					Growth (F1)	NOAEL	NA	6 mg/kg-d	NA	NA	6.00E+00	NA	
Heptachlor	Sprague-Dawley Rats	F0	Oral gavage	Control and 2 doses: 4.2 or 8.4 mg/kg-d	Growth (F0)	LOAEL	NA	4.2 mg/kg-d	NA	NA	NA	4.20E+00	Purkerson-Parker et al (2001)
		F1	Oral gavage	Control and 3 doses: 0.3, 1.0, or 3.0 mg/kg-d	Survival (F1)	LOAEL	NA	3 mg/kg-d	NA	NA	NA	3.00E+00	
									All Results	Minimum	5.56E-01	2.22E+00	
										Maximum	6.00E+00	4.50E+00	
										Average	3.83E+00	3.48E+00	
										Geomean	2.93E+00	3.35E+00	
										N	5	4	

Note:
Summarized from Kielhorn et al (2006).
TRVs generated using rat data are body weight-scaled to the evaluated mammalian receptors (except for mink).
A separate TRV was developed for mink (see text).

Table 2-5. Data Sources Used to Develop Total PCBs Toxicity Reference Values for the Mink
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	NOAEL	LOAEL	Calculated TRV_{NOAEL} (mg/kg-day)	Calculated TRV_{LOAEL} (mg/kg-day)	Include in TRV Calculation?	Source/Comments
Total PCBs	Aroclor 1254	105 days	Repro	Oral in diet	Two dose levels: 0.64 and 3.57 mg/kg	LOAEL	---	0.64 mg/kg	---	8.77E-02	Yes	Platonow and Karstad (1973)
Total PCBs	Aroclor 1254	4.5 months (135 days)	Repro	Oral in diet	Three dose levels: 1, 5, and 15 ppm in diet	NOAEL, LOAEL	1 ppm in diet	5 ppm in diet	1.37E-01	6.85E-01	Yes	Aulerich and Ringer (1977)
Total PCBs	Aroclor 1254	102 days	Repro	Oral in diet	Single dose of 2.5 ppm in diet	LOAEL	---	2.5 ppm in diet	---	3.07E-01	Yes	Aulerich et al (1985)
Total PCBs	Aroclor 1254	28 days	Growth, Survival	Oral in diet	Five dose levels: 10, 18, 32.4, 58.3 and 105 ppm in diet	NOAEL, LOAEL	18 ppm	32.4 ppm	3.35E+00	6.03E+00	No	Hornshaw et al (1986b) Study assessed both adult and young mink. Values shown are in adult mink, which were more sensitive (see text for discussion). Not included in summary calculations since exposure period was not chronic.
Total PCBs	Aroclor 1254	185 days	Survival, Repro	Oral in diet	Single dose of 1 ppm in diet	LOAEL	---	1 ppm in diet	---	1.80E-01	Yes	Wren et al (1987). TRV values reported by Fuchsman et al (2008).
Total PCBs	Environmental PCBs	182 days	Repro	Oral in diet	Three dose levels: 10%, 20% or 40% Saginaw Bay carp Equivalent to 0.72, 1.53 and 2.56 ppm of total PCBs	NOAEL, LOAEL	0.015 ppm (control)	0.72 ppm	2.06E-03	9.93E-02	Yes	Tillitt et al (1996)
Total PCBs	Clophen A50	12 months (365 days)	Repro	Oral in diet	Two dose levels: 0.1 and 0.3 mg/animal-day	NOAEL, LOAEL	0.1 mg/animal-d	0.3 mg/animal-d	8.10E-02	2.40E-01	Yes	Brunström et al (2001).
Total PCBs	Environmental PCBs	160 days	Growth, Repro, Survival	Oral in diet	Five dose levels using Housatonic River Fish: 0.34, 0.61, 0.96, 1.6, and 3.7 ppm as total PCBs	NOAEL, LOAEL	1.6 ppm in diet	3.7 ppm in diet	1.69E-01	4.14E-01	Yes	Bursian et al (2003) and Bursian et al (2006a) Trace levels of pesticides also reported. Additional chemical parameters were not evaluated by the authors.
Total PCBs	Environmental PCBs	160 days	Growth, Repro, Survival	Oral in diet	Three dose levels using Saginaw River Fish: 0.83, 1.1, and 1.7 ppm as total PCBs	NOAEL	1.7 ppm in diet	---	2.33E-01	---	Yes	Bursian et al (2006b)
								Min	2.06E-03	8.77E-02		
								Max	2.33E-01	6.85E-01		
								Average	1.24E-01	2.88E-01		
								Geometric Mean	6.17E-02	2.29E-01		

Note:
Study durations shown were as reported by the authors and were also adjusted to days to facilitate comparisons between studies.

Table 2-6. Data Sources Used to Develop Total PCBs Toxicity Reference Values for Mice
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	NOAEL	LOAEL	Calculated TRV_{NOAEL} (mg/kg-day)	Calculated TRV_{LOAEL} (mg/kg-day)	Source/Comments
Total PCBs	Aroclor 1254	9 to 18 months (270 to 540 days)	Repro	Oral in diet	10 ppm in diet	LOAEL	---	10 mg/kg	---	1.27E+00	Linzey (1987)
Total PCBs	Aroclor 1254	F1 generation 4 to 12 weeks (28 to 84 days)	Repro, Survival	Oral in diet	10 ppm in diet	LOAEL	---	10 mg/kg	---	1.27E+00	Linzey (1988) [a]
Total PCBs	Aroclor 1254	21 days	Survival	Oral in diet	Four dose levels: 2.5, 25, 50 and 100 ppm	NOAEL, LOAEL	2.5 ppm	25 ppm in diet	3.60E-01	3.60E+00	Simmons and McKee (1992) TRV_{NOAEL} value reported by EPA (2002).
Total PCBs	Aroclor 1254	3 generations (1 year) (365 days)	Repro	Oral in diet	5 ppm in diet	LOAEL	---	5 mg/kg	---	6.80E-01	McCoy et al (1995).
Total PCBs	Aroclors 1242 and 1254	4 months (120 days)	Growth, Repro,	Oral in diet	Two dose levels: 10 and 25 ppm as total PCBs	NOAEL, LOAEL	10 ppm in diet	25 ppm in diet	2.64E+00	6.19E+00	Voltura and French (2007) PCB mixture was 2:1 Aroclor 1242:Aroclor 1254.
								Range	0.36 - 2.64	0.68 - 6.19	
								Average	1.500	2.602	
								Geometric Mean	0.975	1.895	

Note:
The geometric means of the TRVs were body-weight scaled to derive TRVs for mammals other than mink. TRVs specific for mink were available
Study durations shown were as reported by the authors and were also adjusted to days to facilitate comparisons between studies.
[a] FI generation were offspring of parents from prior study (Linzey, 1987).

Table 2-7. Data Sources Used to Develop Toxicity Reference Values for PCDD/F-TEQ and PCB-TEQ for Mink
Rolling Knolls Landfill, Chatham, New Jersey

Chemical Form	Exposure Media	Diet Concentration (ng/kg_{ww} feed) NOAEL	Diet Concentration (ng/kg_{ww} feed) LOAEL	Food Intake (kg_{ww}/day)	Body Weight (kg)	TRV_{NOAEL} (mg/kg-day)	TRV_{LOAEL} (mg/kg-day)	Source
PCBs, PCDD/Fs	Houstonic River (MA) fish	12.1	50.4	0.137	1	1.66E-06	6.90E-06	Bursian et al. (2006b)
PCBs, PCDD/Fs	Saginaw River (MI) fish	56.6	---	0.137	1	7.75E-06	---	Bursian et al. (2006a)
PCBs, PCDD/Fs	Saginaw Bay (MI) carp	---	16.8	0.137	1	---	2.30E-06	Heaton et al. (1995)
2,3,7,8-TCDF	Spiked lab diet	26	242	0.137	1	3.56E-06	3.32E-05	Zwiernik et al. (2009)
				All Data	Average	4.32E-06	1.41E-05	
					Geomean	3.58E-06	8.08E-06	
				Bounded Studies	Average	2.61E-06	2.00E-05	
					Geomean	2.43E-06	1.51E-05	

Notes:

Dietary NOAEL and LOAEL values from Blankenship et al (2008).

Body Weight for mink from USEPA (1993).

Food ingestion rate from Bleavins and Aulerich (1981), as reported in Sample and Suter (1994).

Table 2-8. Data Sources Used to Develop Toxicity Reference Values for PCDD/F-TEQ and PCB-TEQ for Mammals Other than Mink
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Study Type	Test Organism	Study Duration	Endpoints	Exposure Route	Dietary Concentration(s)	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	TRV_{NOAEL} (mg/kg-day)	TRV_{LOAEL} (mg/kg-day)	Include for TRV calculation?	Source/Comments
2,3,7,8-TCDD	Lab	Sprague Dawley Rats	13 weeks (91 days)	Growth	Gavage	Control and four daily doses: 0.71, 7.1, 71.4 and 714 ng/kg$_{bw}$-day.	NOAEL, LOAEL	7.1 ng/kg$_{bw}$-day	71.4 ng/kg$_{bw}$-day	7.10E-06	7.14E-05	Y	Kociba et al (1976)
2,3,7,8-TCDD	Lab	Sprague Dawley Rats	2 years	Growth	Gavage	Control and three daily doses: 0.001, 0.01, 0.1 µg/kg$_{bw}$-day	NOAEL, LOAEL	0.001 µg/kg$_{bw}$-day	0.01 µg/kg$_{bw}$-day	1.00E-06	1.00E-05	Y	Kociba et al (1978)
2,3,7,8-TCDD	Lab	Rats	Three generations	Reproduction	Diet	Control and three daily doses: 0.001, 0.01 and 0.1 µg/kg$_{bw}$-day	NOAEL, LOAEL	0.001 µg/kg$_{bw}$-day	0.01 µg/kg$_{bw}$-day	1.00E-06	1.00E-05	Y	Murray et al (1979)
2,3,7,8-TCDD	Lab	Sprague Dawley Rats (Female)	128 days	Growth	Gavage	Control and five daily doses: 0.85, 3.4, 13.6, 54.3 and 217 ng/kgbw-day.	NOAEL, LOAEL	54.3 ng/kg$_{bw}$-day	217 ng/kg$_{bw}$-day	5.43E-05	2.17E-04	Y	Croutch et al (2005). Average daily doses reported by USEPA (2012) in summary of this study. Dosing scheme was initial loading of 0, 0.0125, 0.05, 0.2, 0.8, or 3.2 µg/kgbw at time zero followed by a "maintenance dose" dose rates about one tenth of the loading dose every 3 days.
2,3,7,8-TCDD	Lab	Sprague Dawley Rats (Female)	Two years	Survival	Gavage	Control and five doses; 3, 10, 22, 46 and 100 ng/kg$_{bw}$ Five days per week	NOAEL	100 ng/kg$_{bw}$	--	7.14E-05	--	Y	Walker et al (2006). Dose concentrations were converted to averaged daily doses (i.e., TRV units) by the authors.
				Growth			NOAEL, LOAEL	10 ng/kg$_{bw}$	22 ng/kg$_{bw}$	7.10E-06	1.57E-05	Y	
								All Studies	Average	2.37E-05	6.48E-05		
									Geomean	7.62E-06	3.00E-05		
									N	6	5		
								Bounded Studies	Average	1.41E-05	6.48E-05		
									Geomean	4.87E-06	3.00E-05		
									N	5	5		

Notes:
LOAEL = lowest observed adverse effect level
NOAEL = no observed adverse effect level
TRV = toxicity reference value

Table 2-9. Data Sources Used to Develop Mammalian Toxicity Reference Values for Cyanide
Rolling Knolls Landfill, Chatham, New Jersey

Chemical Form	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Ingestion Rate (g_{food}/day) or (mL_{water}/day)	Body Weight (kg)	TRV_{NOAEL} (mg/kg-day)	TRV_{LOAEL} (mg/kg-day)	Same TRV used in Work Plan?	Source/Comments
NaCN	Rats	19 days pre-gestation; gestation and lactation; offspring 28d post-weaning	Growth, survival	Oral in diet	Single dose; 500 mg/kg in food	NOAEL	500 mg/kg in food	---	37.5	0.273	6.87E+01	6.87E+02	◆	Tewe and Maner (1981); body weight and ingestion rate from study. Sample et al (1986) assumed TRV_{LOAEL} was ten times the TRV_{NOAEL} developed from this study.
NaCN	Rats (F344)	13 weeks	Reproduction	Oral in water	Five doses (plus control): 3, 10, 30, 100 and 300 mg/L	NOAEL, LOAEL	Males only; 100 mg/L	Males only; 300 mg/L	NA	NA	4.50E+00	1.25E+01		NTP (1993); No relevant effects on female rats.
NaCN	Mice ($B6C3F_1$)	13 weeks	Growth, Survival	Oral in water	Five doses (plus control): 3, 10, 30, 100 and 300 mg/L	NOAEL	Females only; 300 mg/L	---	NA	NA	2.88E+01	---		NTP (1993); No relevants effects on male mice. Daily dose calculated by NTP.
									All Species	Average	3.40E+01	3.50E+02		
										Geometric Mean	2.07E+01	9.27E+01		
									Rats Only	Average	3.66E+01	3.50E+02		
										Geometric Mean	1.76E+01	9.27E+01		

Notes:
NA = not available

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Table 3-1a. Data Sources Used to Develop Food-Chain Toxicity Reference Values for Avian Species Other Than Ducks
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Selected TRV_{NOAEL} (mg/kg_{bw}-day)	Selected TRV_{LOAEL} (mg/kg_{bw}-day)	Source/Comments
Semivolatile Organics												
Bis(2-ethyl hexyl) phthalate	BEHP	Ringed doves	28 days	Reproduction	Oral	Single dose: 10 mg/kg in diet	NOAEL	10 mg/kg in diet	---	1.11E+00	---	Peakall et al (1974); Sample et al (1996) used assumed body weight and ingestoin rate to calculate TRV_{NOAEL}. TRV_{LOAEL} could not be derived from study.
Butylbenzylphthalate	BEHP	Ringed doves	28 days	Reproduction	Oral	Single dose: 10 mg/kg in diet	NOAEL	10 mg/kg in diet	---	1.11E+00	---	Peakall et al (1974); Sample et al (1996) used assumed body weight and ingestoin rate to calculate TRV_{NOAEL}. TRV_{LOAEL} could not be derived from study.
Pentachlorophenol	Pentachlorophenol	Mallard ducks	11 days	Growth, reproduction, survival	Oral		NOAEL, LOAEL	40.9 mg/kg-d	92.9 mg/kg-d	4.09E+01	9.29E+01	USEPA (2007b)
Benzo(a)anthracene	Dimethylbenz(a)anthracene	European starling	5 days	Growth	Oral	Control and two doses: 2 and 20 mg/kg-c	NOAEL, LOAEL	2 mg/kg-d	20 mg/kg-d	2.00E-01	2.00E+00	USEPA (2007a), H-PAH.
Benzo(a)pyrene	Dimethylbenz(a)anthracene	European starling	5 days	Growth	Oral	Control and two doses: 2 and 20 mg/kg-c	NOAEL, LOAEL	2 mg/kg-d	20 mg/kg-d	2.00E-01	2.00E+00	USEPA (2007a), H-PAH.
Chrysene	Dimethylbenz(a)anthracene	European starling	5 days	Growth	Oral	Control and two doses: 2 and 20 mg/kg-c	NOAEL, LOAEL	2 mg/kg-d	20 mg/kg-d	2.00E-01	2.00E+00	USEPA (2007a), H-PAH.
Dibenz(a,h)anthracene	Dimethylbenz(a)anthracene	European starling	5 days	Growth	Oral	Control and two doses: 2 and 20 mg/kg-c	NOAEL, LOAEL	2 mg/kg-d	20 mg/kg-d	2.00E-01	2.00E+00	USEPA (2007a), H-PAH.
Naphthalene	Naphthalene	Bobwhite quail	5 days	Growth, survival	Oral	Control or six test diets (316, 562, 1,000, 1,780, 3,160 and 5,620 mg/kg).	NOAEL	5,620 mg/kg in diet	---	1.65E+02	1.65E+03	USEPA (2007a), L-PAH (based on napthalane).
Pesticides												
2,4'-DDD	DDT and metabolites	Multiple species	5 to 329 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.0396 to 100 mg/kg-d	0.396 to 200 mg/kg-d	4.11E+00	1.46E+01	USEPA, 2007c
2,4'-DDE	DDT and metabolites	Multiple species	5 to 329 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.0396 to 100 mg/kg-d	0.396 to 200 mg/kg-d	4.11E+00	1.46E+01	USEPA, 2007c
2,4'-DDT	DDT and metabolites	Multiple species	5 to 329 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.0396 to 100 mg/kg-d	0.396 to 200 mg/kg-d	4.11E+00	1.46E+01	USEPA, 2007c
4,4'-DDE	DDT and metabolites	Multiple species	5 to 329 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.0396 to 100 mg/kg-d	0.396 to 200 mg/kg-d	4.11E+00	1.46E+01	USEPA, 2007c
4,4'-DDD	DDT and metabolites	Multiple species	5 to 329 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.0396 to 100 mg/kg-d	0.396 to 200 mg/kg-d	4.11E+00	1.46E+01	USEPA, 2007c
4,4'-DDT	DDT and metabolites	Multiple species	5 to 329 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.0396 to 100 mg/kg-d	0.396 to 200 mg/kg-d	4.11E+00	1.46E+01	USEPA, 2007c
Aldrin	Dieldrin	Multiple species	14 to 360 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.0537 to 10 mg/kg-d	0.179 to 15 mg/kg-d	7.52E-01	1.61E+00	USEPA (2007d)
alpha-Chlordane	Chlordane mixture	Red-winged blackbirds	84 days	Survival	Oral	Control diet or three test diets containing 10, 50 and 100 mg/kg	NOAEL, LOAEL	10 mg/kg diet	50 mg/kg diet	2.14E+00	1.07E+01	Stickel et al (1983). TRV_{NOAEL} and TRV_{LOAEL} calculated by Sample et al (1996).
beta-BHC	gamma-BHC (Lindane)	Mallard ducks	8 weeks (56 days)	Repro	Oral	1 test dose: 20 mg/kg-day	LOAEL	NA	20 mg/kg-d	2.00E-01	2.00E+00	Chakravarty and Lahiri (1986), only a LOAEL was available. Sample et al (1996) assumed TRV_{NOAEL} is one-tenth this value.
delta-BHC	gamma-BHC (Lindane)	Mallard ducks	8 weeks (56 days)	Repro	Oral	1 test dose: 20 mg/kg-day	LOAEL	NA	20 mg/kg-d	2.00E-01	2.00E+00	Chakravarty and Lahiri (1986), only a LOAEL was available. Sample et al (1996) assumed TRV_{NOAEL} is one-tenth this value.
Dieldrin	Dieldrin	Multiple species	14 to 360 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.0537 to 10 mg/kg-d	0.179 to 15 mg/kg-d	7.52E-01	1.61E+00	USEPA, 2007aa
Endosulfan I	Endosulfan	gray partridges	4 weeks (28 days)	Repro	Oral	Control diet or three test diets: 5, 25 and 125 mg/kg	NOAEL	125 mg/kg in diet	NA	1.00E+01	1.00E+02	Abiola (1992), only a NOAEL was available. TRV_{NOAEL} calculated by Sample et al (1996). TRV_{LOAEL} assumed to be 10 times greater.
Endosulfan sulfate	Endosulfan	gray partridges	4 weeks (28 days)	Repro	Oral	Control diet or three test diets: 5, 25 and 125 mg/kg	NOAEL	126 mg/kg in diet	NA	1.00E+01	1.00E+02	Abiola (1992), only a NOAEL was available. TRV_{NOAEL} calculated by Sample et al (1996). TRV_{LOAEL} assumed to be 10 times greater.
Endrin	Endrin	Ring-necked pheasant, screech owl	83 to 120 days	Reproduction, survival	Oral	Multiple	NOAEL, LOAEL	1 to 2 mg/kg in diet	0.75 to 10 mg/kg in diet	4.10E-02	1.90E-01	TRVs are geometric means of NOAELs and LOAELs from two studies [Dewitt (1965) and Fleming et al (1982)] . See Table 3-2.
Endrin aldehyde	Endrin	Ring-necked pheasant, screech owl	83 to 120 days	Reproduction, survival	Oral	Multiple	NOAEL, LOAEL	1 to 2 mg/kg in diet	0.75 to 10 mg/kg in diet	4.10E-02	1.90E-01	TRVs are geometric means of NOAELs and LOAELs from two studies [Dewitt (1965) and Fleming et al (1982)] . See Table 3-2.

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Table 3-1a. Data Sources Used to Develop Food-Chain Toxicity Reference Values for Avian Species Other Than Ducks
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Selected TRV_{NOAEL} (mg/kg_{bw}-day)	Selected TRV_{LOAEL} (mg/kg_{bw}-day)	Source/Comments
Endrin ketone	Endrin	Ring-necked pheasant, screech owl	83 to 120 days	Reproduction, survival	Oral	Multiple	NOAEL, LOAEL	1 to 2 mg/kg in diet	0.75 to 10 mg/kg in diet	4.10E-02	1.90E-01	TRVs are geometric means of NOAELs and LOAELs from two studies [Dewitt (1965) and Fleming et al (1982)] . See Table 3-2.
gamma-BHC (Lindane)	gamma-BHC (Lindane)	Mallard ducks	8 weeks (56 days)	Repro	Oral	1 test dose: 20 mg/kg-day	LOAEL	NA	20 mg/kg-d	2.00E-01	2.00E+00	Chakravarty and Lahiri (1986), only a LOAEL was available. Sample et al (1996) assumed TRV_{NOAEL} is one-tenth this value.
gamma-Chlordane	Chlordane mixture	Red-winged blackbirds	84 days	Survival	Oral	Control diet or three test diets containing 10, 50 and 100 mg/kg	NOAEL, LOAEL	10 mg/kg diet	50 mg/kg diet	2.14E+00	1.07E+01	Stickel et al (1983). TRV_{NOAEL} and TRV_{LOAEL} calculated by Sample et al (1996).
Heptachlor	NA	Quail	5 days	Survival	NA	NA	LOAEL (acute)	NA	6.5 mg/kg-d (acute)	6.50E-02	6.50E-01	Hill and Camardese (1986) as calculated in USEPA (1999)
Heptachlor epoxide	NA	Quail	5 days	Survival	NA	NA	LOAEL (acute)	NA	6.5 mg/kg-d (acute)	6.50E-02	6.50E-01	Hill and Camardese (1986) as calculated in USEPA (1999)
Aroclor PCBs												
Aroclor-1242	Aroclor 1254 or "environmental PCBs"	Multiple species	Varies (42 to 730 days)	Growth, Repro	Oral	Multiple	NOAEL, LOAEL	Varies	Varies	3.16E-01	2.32E+00	Bounded value for all birds other than ducks. TRV values shown are the geometric means from multiple studies. See Table 3-3 for compilation.
Aroclor-1248	Aroclor 1254 or "environmental PCBs"	Multiple species	Varies (42 to 730 days)	Growth, Repro	Oral	Multiple	NOAEL, LOAEL	Varies	Varies	3.16E-01	2.32E+00	Bounded value for all birds other than ducks. TRV values shown are the geometric means from multiple studies. See Table 3-3 for compilation.
Aroclor-1254	Aroclor 1254 or "environmental PCBs"	Multiple species	Varies (42 to 730 days)	Growth, Repro	Oral	Multiple	NOAEL, LOAEL	Varies	Varies	3.16E-01	2.32E+00	Bounded value for all birds other than ducks. TRV values shown are the geometric means from multiple studies. See Table 3-3 for compilation.
Aroclor-1260	Aroclor 1254 or "environmental PCBs"	Multiple species	Varies (42 to 730 days)	Growth, Repro	Oral	Multiple	NOAEL, LOAEL	Varies	Varies	3.16E-01	2.32E+00	Bounded value for all birds other than ducks. TRV values shown are the geometric means from multiple studies. See Table 3-3 for compilation.
Total PCBs	Aroclor 1254 or "environmental PCBs"	Multiple species	Varies (42 to 730 days)	Growth, Repro	Oral	Multiple	NOAEL, LOAEL	Varies	Varies	3.16E-01	2.32E+00	Bounded value for all birds other than ducks. TRV values shown are the geometric means from multiple studies. See Table 3-3 for compilation.
TEQs												
PCB-TEQ Congeners	2,3,7,8-TCDD	Ring-necked pheasants	10 weeks	Reproduction	i.p. (weekly)	Equivalent daily doses: 1.4E-06, 1.4E-05, and 1.4E-04 mg/kg_{bw}-day	NOAEL, LOAEL	1.4E-05 mg/kg_{bw}-day	1.4E-04 mg/kg_{bw}-day	1.40E-05	1.40E-04	Value for all birds. Nosek et al (1992).
PCDD/F-TEQ Congeners	2,3,7,8-TCDD	Ring-necked pheasants	10 weeks	Reproduction	i.p. (weekly)	Equivalent daily doses: 1.4E-06, 1.4E-05, and 1.4E-04 mg/kg_{bw}-day	NOAEL, LOAEL	1.4E-05 mg/kg_{bw}-day	1.4E-04 mg/kg_{bw}-day	1.40E-05	1.40E-04	Value for all birds. Nosek et al (1992).
Metals and Cyanide												
Antimony	No Data	---	---	---	---	---	---	---	---	---	---	No toxicity data available to develop TRVs.
Arsenic	Multiple	Chicken, duck	14 to 70 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	2.24 to 17.3 mg/kg-day	1.49 to 17.3 mg/kg-day	3.70E+00	4.51E+00	USEPA (2005b). Geometric means of unbounded NOAELs and LOAELs across all avian species. No bounded values were available.
Barium	Multiple	Chicken (chicks)	4 wks (28 days)	Mortality	Oral in diet	Eight dose levels: 250, 500, 1000, 2000, 4000, 8000, 16,000, and 32,000 ppm in diet	NOAEL, LOAEL	2000 ppm	4000 ppm	2.08E+01	4.17E+01	Value for all birds. Johnson et al. (1960), as cited by Sample et al. (1996).
Cadmium	Multiple	Chicken, Japanese quail	14 to 360 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	0.593 to 22.3 mg/kg-d	2.37 to 44.6 mg/kg-d	2.03E+00	5.96E+00	USEPA (2005d).
Chromium	Multiple	Chicken	15 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	37.7 mg/kg-d	75.4 mg/kg-d	3.77E+01	7.54E+01	USEPA (2008).
Cobalt	Multiple	Chicken	14 to 35 days	Growth, survival	Oral in diet	Multiple	NOAEL, LOAEL	3.89 to 12.3 mg/kg-d	7.8 to 26.7 mg/kg-d	5.45E+00	1.11E+01	USEPA (2005e). Values shown are geometric means of NOAELs and LOAELs.
Copper	Multiple	Chicken, turkey	5 to 336 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	2.34 to 239 mg/kg-d	4.68 to 318 mg/kg-d	2.01E+01	3.60E+01	USEPA (2007e). Values shown are geometric means of NOAELs and LOAELs.
Lead	Multiple	American kestrel, chicken, Japanese quail, and pigeon	7 to 84 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	0.194 to 160 mg/kg-d	1.94 to 625 mg/kg-d	1.05E+01	5.38E+01	USEPA (2005f). Values shown are geometric means of NOAELs and LOAELs.

Table 3-1a. Data Sources Used to Develop Food-Chain Toxicity Reference Values for Avian Species Other Than Ducks
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Selected TRV_{NOAEL} (mg/kg_{bw}-day)	Selected TRV_{LOAEL} (mg/kg_{bw}-day)	Source/Comments
Manganese	Multiple	Chicken and turkey	14 to 21 days		Oral	Multiple	NOAEL, LOAEL	215 to 302 mg/kg-d	348 to 431 mg/kg-d	2.57E+02	3.77E+02	USEPA (2007f). Values shows are geometric means across all species.
Mercury, inorganic	Mercuric chloride	Japanese quail	1 year (365 days)	Reproduction	Oral in diet	Five dose levels: 2, 4, 8, 16, and 32 mg/kg Hg in diet.	NOAEL, LOAEL	4 mg/kg-d	8 mg/kg-d	4.50E-01	9.00E-01	Hill and Schaffner (1976), as cited by Sample et al. (1996)
Mercury, methyl	Methyl mercury	Multiple species	Varies	Reproduction	Oral in diet	Multiple	NOAEL, LOAEL	0.064 to 0.451 mg/kg-d	0.061 to 0.435 mg/kg-d	1.20E-01	1.56E-01	Geometric means of unbounded NOAEL and LOAEL values across multiple studies and species. See Table 3-4 for compilation.
Nickel	Multiple	Chicken	21 to 42 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	5.76 to 31 mg/kg-d	11.5 to 39.9 mg/kg-d	1.61E+01	2.39E+01	USEPA (2007c). Values shown are geometric means of NOAELs and LOAELs.
Selenium	Multiple	Chicken, Japanese quail	7 to 532 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	0.074 to 28.2 mg/kg-d	0.368 to 29 mg/kg-d	5.47E-01	1.21E+00	USEPA (2007g). Values shown are geometric means of NOAELs and LOAELs.
Silver	Multiple	Chicken and turkey	14 to 35 days	Growth, survival	Oral in diet	Multiple	LOAEL	NA	20.2 to 88.4 mg/kg-day	6.50E+00	6.50E+01	USEPA (2006). Unbounded dataset. Values shown is the geometric mean of LOAELs for growth and survival across multiple studies. TRV_{NOAEL} assumed to be one tenth the TRV_{LOAEL}.
Vanadium	Multiple	Chicken	7 to 175 days	Growth, survival	Oral in diet	Multiple	NOAEL, LOAEL	0.244 to 6.37 mg/kg-d	0.413 to 14.8 mg/kg-d	1.24E+00	2.55E+00	USEPA (2005g).
Zinc	Multiple	Chicken, Japanese quail, and turkey	7 to 140 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	24.7 to 367 mg/kg-d	66.5 to 503 mg/kg-d	1.00E+02	1.74E+02	USEPA (2007i).
Cyanide	Sodium Cyanide	Multiple species	1 day	Lethality	Oral in diet	Four - five dose rates	Acute LD_{50}	NA	NA	1.40E-01	1.40E+00	Wiemeyer et al (1986). Geomean across six species; TRV_{NOAEL} calculated by applying a UF of 100 to LD_{50} from most sensitive species (kestrel). Assumed LOAEL TRV was 10 times the NOAEL TRV

Note:
Only the results from the bounded studies are shown, unless noted
When more than four avian species were reported as test oranisms these are shown "multiple species" in this table.

Table 3-1b. Data Sources Used to Develop Food-Chain Toxicity Reference Values for the Duck
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Selected TRV_{NOAEL} (mg/kg_{bw}-day)	Selected TRV_{LOAEL} (mg/kg_{bw}-day)	Source/Comments
Semivolatile Organics												
Bis(2-ethyl hexyl) phthalate	BEHP	Ringed doves	28 days	Reproduction	Oral	Single dose: 10 mg/kg in diet	NOAEL	10 mg/kg in diet	---	1.11E+00	---	Peakall et al (1974); Sample et al (1996) used assumed body weight and ingestoin rate to calculated TRVNOAEL. TRVLOAEL could not be derived from study.
Butylbenzylphthalate	BEHP	Ringed doves	28 days	Reproduction	Oral	Single dose: 10 mg/kg in diet	NOAEL	10 mg/kg in diet	---	1.11E+00	---	Peakall et al (1974); Sample et al (1996) used assumed body weight and ingestoin rate to calculated TRVNOAEL. TRVLOAEL could not be derived from study.
Pentachlorophenol	Pentachlorophenol	Mallard ducks	11 days	Growth, reproduction, survival	Oral		NOAEL, LOAEL	40.9 mg/kg-d	92.9 mg/kg-d	4.09E+01	9.29E+01	USEPA (2007b)
Benzo(a)anthracene	Dimethylbenz(a)anthracene	European starling	5 days	Growth	Oral	Control and two doses: 2 and 20 mg/kg-d	NOAEL, LOAEL	2 mg/kg-d	20 mg/kg-d	2.00E-01	2.00E+00	USEPA (2007a), H-PAH.
Benzo(a)pyrene	Dimethylbenz(a)anthracene	European starling	5 days	Growth	Oral	Control and two doses: 2 and 20 mg/kg-d	NOAEL, LOAEL	2 mg/kg-d	20 mg/kg-d	2.00E-01	2.00E+00	USEPA (2007a), H-PAH.
Chrysene	Dimethylbenz(a)anthracene	European starling	5 days	Growth	Oral	Control and two doses: 2 and 20 mg/kg-d	NOAEL, LOAEL	2 mg/kg-d	20 mg/kg-d	2.00E-01	2.00E+00	USEPA (2007a), H-PAH.
Dibenz(a,h)anthracene	Dimethylbenz(a)anthracene	European starling	5 days	Growth	Oral	Control and two doses: 2 and 20 mg/kg-d	NOAEL, LOAEL	2 mg/kg-d	20 mg/kg-d	2.00E-01	2.00E+00	USEPA (2007a), H-PAH.
Naphthalene	Naphthalene	Bobwhite quail	5 days	Growth, survival	Oral	Control or six test diets (316, 562, 1,000, 1,780, 3,160 and 5,620 mg/kg).	NOAEL	5,620 mg/kg in diet	---	1.65E+02	1.65E+03	USEPA (2007a), L-PAH (based on napthalane).
Pesticides												
2,4'-DDD	DDT and metabolites	Mallard ducks	10 to 365 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.0563 to 66.2 mg/kg-d	0.281 to 132 mg/kg-d	5.21E-01	3.40E+00	USEPA (2007c)
2,4'-DDE	DDT and metabolites	Mallard ducks	11 to 365 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.0563 to 66.2 mg/kg-d	0.281 to 132 mg/kg-d	5.21E-01	3.40E+00	USEPA (2007c)
2,4'-DDT	DDT and metabolites	Mallard ducks	12 to 365 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.0563 to 66.2 mg/kg-d	0.281 to 132 mg/kg-d	5.21E-01	3.40E+00	USEPA (2007c)
4,4'-DDE	DDT and metabolites	Mallard ducks	13 to 365 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.0563 to 66.2 mg/kg-d	0.281 to 132 mg/kg-d	5.21E-01	3.40E+00	USEPA (2007c)
4,4'-DDD	DDT and metabolites	Mallard ducks	14 to 365 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.0563 to 66.2 mg/kg-d	0.281 to 132 mg/kg-d	5.21E-01	3.40E+00	USEPA (2007c)
4,4'-DDT	DDT and metabolites	Mallard ducks	15 to 365 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.0563 to 66.2 mg/kg-d	0.281 to 132 mg/kg-d	5.21E-01	3.40E+00	USEPA (2007c)
Aldrin	Dieldrin	Mallard ducks	24 to 336 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.071 to 2.21 mg/kg-d	0.56 to 4.42 mg/kg-d	2.36E-01	2.44E+00	USEPA (2007d)
alpha-Chlordane	Chlordane mixture	Red-winged blackbirds	84 days	Survival	Oral	Control diet or three test diets containing 10, 50 and 100 mg/kg	NOAEL, LOAEL	10 mg/kg diet	50 mg/kg diet	2.14E+00	1.07E+01	Stickel et al (1983). TRV_{NOAEL} and TRV_{LOAEL} calculated by Sample et al (1996).
beta-BHC	gamma-BHC (Lindane)	Mallard ducks	8 weeks (56 days)	Repro	Oral	1 test dose: 20 mg/kg-day	LOAEL	NA	20 mg/kg-d	2.00E-01	2.00E+00	Chakravarty and Lahiri (1986), only a LOAEL was available. TRVNOAEL calculated by Sample et al (1996).
delta-BHC	gamma-BHC (Lindane)	Mallard ducks	8 weeks (56 days)	Repro	Oral	1 test dose: 20 mg/kg-day	LOAEL	NA	20 mg/kg-d	2.00E-01	2.00E+00	Chakravarty and Lahiri (1986), only a LOAEL was available. TRVNOAEL calculated by Sample et al (1996).
Dieldrin	Dieldrin	Mallard ducks	24 to 336 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	0.071 to 2.21 mg/kg-d	0.56 to 4.42 mg/kg-d	2.36E-01	2.44E+00	USEPA (2007d)
Endosulfan I	Endosulfan	gray partridges	4 weeks (28 days)	Repro	Oral	Control diet or three test diets: 5, 25 and 125 mg/kg	NOAEL	125 mg/kg in diet	NA	1.00E+01	1.00E+02	Abiola (1992), only a NOAEL was available. TRV_{NOAEL} calculated by Sample et al (1996). TRV_{LOAEL} assumed to be 10 times greater.
Endosulfan sulfate	Endosulfan	gray partridges	4 weeks (28 days)	Repro	Oral	Control diet or three test diets: 5, 25 and 125 mg/kg	NOAEL	126 mg/kg in diet	NA	1.00E+01	1.00E+02	Abiola (1992), only a NOAEL was available. TRV_{NOAEL} calculated by Sample et al (1996). TRV_{LOAEL} assumed to be 10 times greater.

Table 3-1b. Data Sources Used to Develop Food-Chain Toxicity Reference Values for the Duck
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Selected TRV_{NOAEL} (mg/kg_{bw}-day)	Selected TRV_{LOAEL} (mg/kg_{bw}-day)	Source/Comments
Endrin	Endrin	Mallard ducks	44 to 227 days	Repro	Oral	Multiple	NOAEL, LOAEL	0.5 to 3 mg/kg in diet	3 mg/kg in diet	1.65E-01	3.00E-01	TRVs are geometric means of NOAELs and LOAELs from two studies. See Table 3-2.
Endrin aldehyde	Endrin	Mallard ducks	44 to 227 days	Repro	Oral	Multiple	NOAEL, LOAEL	0.5 to 3 mg/kg in diet	3 mg/kg in diet	1.65E-01	3.00E-01	TRVs are geometric means of NOAELs and LOAELs from two studies. See Table 3-2.
Endrin ketone	Endrin	Mallard ducks	44 to 227 days	Repro	Oral	Multiple	NOAEL, LOAEL	0.5 to 3 mg/kg in diet	3 mg/kg in diet	1.65E-01	3.00E-01	TRVs are geometric means of NOAELs and LOAELs from two studies. See Table 3-2.
gamma-BHC (Lindane)	gamma-BHC (Lindane)	Mallard ducks	8 weeks (56 days)	Repro	Oral	1 test dose: 20 mg/kg-day	LOAEL	NA	20 mg/kg-d	2.00E-01	2.00E+00	Chakravarty and Lahiri (1986), only a LOAEL was available. TRVNOAEL calculated by Sample et al (1996).
gamma-Chlordane	Chlordane mixture	Red-winged blackbirds	84 days	Survival	Oral	Control diet or three test diets containing 10, 50 and 100 mg/kg	NOAEL, LOAEL	10 mg/kg diet	50 mg/kg diet	2.14E+00	1.07E+01	Stickel et al (1983). TRV_{NOAEL} and TRV_{LOAEL} calculated by Sample et al (1996).
Heptachlor	NA	Quail	5 days	Survival	NA	NA	LOAEL (acute)	NA	6.5 mg/kg-d (acute)	6.50E-02	6.50E-01	Hill and Camardese (1986) as calculated in USEPA (1999)
Heptachlor epoxide	NA	Quail	5 days	Survival	NA	NA	LOAEL (acute)	NA	6.5 mg/kg-d (acute)	6.50E-02	6.50E-01	Hill and Camardese (1986) as calculated in USEPA (1999)
Aroclor PCBs												
Aroclor-1242	Aroclor 1254 or "environmental PCBs"	Mallard Duck	2 yrs (730 days)	Reproduction	Oral	25 and 50 ppm in diet	NOAEL, LOAEL	25 ppm in diet	50 ppm in diet	7.00E+00	1.40E+01	Heath (1972), bounded values. See Table 3-3 for compilation of other studies.
Aroclor-1248	Aroclor 1254 or "environmental PCBs"	Multiple species	2 yrs (730 days)	Reproduction	Oral	25 and 50 ppm in diet	NOAEL, LOAEL	25 ppm in diet	50 ppm in diet	7.00E+00	1.40E+01	Heath (1972), bounded values. See Table 3-3 for compilation of other studies.
Aroclor-1254	Aroclor 1254 or "environmental PCBs"	Multiple species	2 yrs (730 days)	Reproduction	Oral	25 and 50 ppm in diet	NOAEL, LOAEL	25 ppm in diet	50 ppm in diet	7.00E+00	1.40E+01	Heath (1972), bounded values. See Table 3-3 for compilation of other studies.
Aroclor-1260	Aroclor 1254 or "environmental PCBs"	Multiple species	2 yrs (730 days)	Reproduction	Oral	25 and 50 ppm in diet	NOAEL, LOAEL	25 ppm in diet	50 ppm in diet	7.00E+00	1.40E+01	Heath (1972), bounded values. See Table 3-3 for compilation of other studies.
Total PCBs	Aroclor 1254 or "environmental PCBs"	Multiple species	2 yrs (730 days)	Reproduction	Oral	25 and 50 ppm in diet	NOAEL, LOAEL	25 ppm in diet	50 ppm in diet	7.00E+00	1.40E+01	Heath (1972), bounded values. See Table 3-3 for compilation of other studies.
TEQs												
PCB-TEQ Congeners	2,3,7,8-TCDD	Ring-necked pheasants	10 weeks	Reproduction	i.p. (weekly)	Equivalent daily doses: 1.4E-06, 1.4E-05, and 1.4E-04 mg/kg_{bw}-day	NOAEL, LOAEL	1.4E-05 mg/kg_{bw}-day	1.4E-04 mg/kg_{bw}-day	1.40E-05	1.40E-04	Value for all birds. Nosek et al (1992).
PCDD/F-TEQ Congeners	2,3,7,8-TCDD	Ring-necked pheasants	10 weeks	Reproduction	i.p. (weekly)	Equivalent daily doses: 1.4E-06, 1.4E-05, and 1.4E-04 mg/kg_{bw}-day	NOAEL, LOAEL	1.4E-05 mg/kg_{bw}-day	1.4E-04 mg/kg_{bw}-day	1.40E-05	1.40E-04	Value for all birds. Nosek et al (1992).
Metals and Cyanide												
Antimony	No Data	---	---	---	---	---	---	---	---	---	---	No toxicity data available to develop TRVs.
Arsenic	Multiple	Chicken, duck	14 to 70 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	2.24 to 17.3 mg/kg-day	1.49 to 17.3 mg/kg-day	3.70E+00	4.51E+00	USEPA (2005b). Geometric means of unbounded NOAELs and LOAELs across all avian species. No bounded values were available.
Barium	Multiple	Chicken (chicks)	4 wks (28 days)	Mortality	Oral in diet	Eight dose levels: 250, 500, 1000, 2000, 4000, 8000, 16,000, and 32,000 ppm in diet	NOAEL, LOAEL	2000 ppm	4000 ppm	2.08E+01	4.17E+01	Value for all birds. Johnson et al. (1960), as cited by Sample et al. (1996).
Cadmium	Multiple	Mallard duck, wood duck	42 to 90 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	1.53 to 12.5 mg/kg-d	21.1 to 37.6 mg/kg-d	3.08E+00	2.56E+01	USEPA (2005d).
Chromium	Multiple	Black duck	185 to 300 days	Growth, reproduction, survival	Oral in diet	Multiple	NOAEL, LOAEL	0.557 to 0.569 mg/kg-d	2.78 to 2.84 mg/kg-d	5.63E-01	2.81E+00	USEPA (2008).
Cobalt	Multiple	Duck	8 days	Growth, survival	Oral in diet	Multiple	NOAEL, LOAEL	14.8 mg/kg-d	148 mg/kg-d	1.48E+01	1.48E+02	USEPA (2005e). Values shown are bounded NOAEL and LOAEL from one study.
Copper	Multiple	Mallard duck	14 to 35 days	Growth, reproduction, survival	Oral in diet, drinking water, or gavage	Multiple	NOAEL, LOAEL	10.2 to 56.8 mg/kg-d	51.6 to 109 mg/kg-d	2.41E+01	7.50E+01	USEPA (2007e). Values shown are geometric means of NOAELs and LOAELs.
Lead	Multiple	Duck	1 to 12 weeks (7 to 84 days)	Growth, reproduction, survival	Oral in diet, drinking water, or gavage	Multiple	NOAEL	2.47 to 66.9 mg/kg-d	NA	1.66E+01	8.50E+01	USEPA (2005f). Values shown are geometric means of NOAELs. TRV_{LOAEL} estimated from LOAEL:NOAEL ratio for all birds TRVs.

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Table 3-1b. Data Sources Used to Develop Food-Chain Toxicity Reference Values for the Duck
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Selected TRV_{NOAEL} (mg/kg_{bw}-day)	Selected TRV_{LOAEL} (mg/kg_{bw}-day)	Source/Comments
Manganese	Multiple	Chicken and turkey	14 to 21 days	Growth, reproduction, survival	Oral	Multiple	NOAEL, LOAEL	215 to 302 mg/kg-d	348 to 431 mg/kg-d	2.57E+02	3.77E+02	USEPA (2007f). Values shows are geometric means across all species. No duck-specific value available.
Mercury, inorganic	Mercuric chloride	Japanese quail	1 year (365 days)	Reproduction	Oral in diet	Five dose levels: 2, 4, 8, 16, and 32 mg/kg Hg in diet.	NOAEL, LOAEL	4 mg/kg-d	8 mg/kg-d	4.50E-01	9.00E-01	Hill and Schaffner (1976), as cited by Sample et al. (1996)
Mercury, methyl	Methyl mercury dicyandiamide	Mallard duck	Varies	Reproduction	Oral in diet	Multiple	NOAEL, LOAEL	0.064 to 0.077 mg/kg-d	0.371 to 0.435 mg/kg-d	7.00E-02	4.02E-01	Geometric means of bounded NOAEL and LOAEL values for ducks. See Table 3-4 for compilation.
Nickel	Multiple	Mallard duck	19 to 90 days	Growth, reproduction, survival	Oral in diet	NR	NOAEL, LOAEL	10.7 mg/kg-d	47 mg/kg-d	1.07E+01	4.70E+01	USEPA (2007c). Values shown are geometric means of NOAELs and LOAELs.
Selenium	Multiple	Mallard duck	7 days to 105 weeks (7 to 735 days)	Growth, reproduction, survival	Oral in diet, drinking water, or gavage	Two-Six dose levels, various amounts	NOAEL, LOAEL	0.212 to 5.84 mg/kg-d	0.425 to 12.3 mg/kg-d	1.29E+00	3.31E+00	USEPA (2007g). Values shown are geometric means of NOAELs and LOAELs.
Silver	Multiple	Mallard duck	14 days to 5 weeks (14 to 35 days)	Growth, survival	Oral in diet	Multiple	LOAEL	NA	98.6 to 401 mg/kg-day	7.96E+00	1.99E+02	USEPA (2006). Values shown is the geometric mean of LOAELs for growth and survival across multiple studies. TRV_{NOAEL} assumed to be one tenth the TRV_{LOAEL}.
Vanadium	Multiple	Mallard duck	15 to 84 days	Survival	Oral in diet	Multiple	NOAEL	12 to 13.4 mg/kg-d	NA	1.99E+01	1.99E+02	USEPA (2005g). $TRVN_{OAEL}$ is the geometric mean of 2 LOAELs. TRV_{NOAEL} assumed one-tenth this value.
Zinc	Multiple	Mallard duck	10 to 60 days	Growth, reproduction, survival	Oral in diet	Multiple	LOAEL	NA	31.2 to 803 mg/kg-d	1.01E+02	1.74E+02	USEPA (2007i). TRV_{LOAEL} is the geometric mean of 5 LOAELs. TRV_{NOAEL} estimated from LOAEL:NOAEL ratio for all birds.
Cyanide	Sodium Cyanide	Multiple species	1 day	Lethality	Oral in diet	Four - five dose rates	Acute LD_{50}	NA	NA	1.40E-01	1.40E+00	Wiemeyer et al (1986). Geomean across six species; TRV_{NOAEL} calculated by applying a UF of 100 to LD_{50} from most sensitive species (kestrel). Assumed LOAEL TRV was 10 times the NOAEL TRV

Note:
Only the results from the bounded studies are shown, unless noted.
When more than four avian species were reported as test oranisms these are shown "multiple species" in this table.

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Table 3-2. Data Sources Used to Develop Avian Toxicity Reference Values for Endrin and Related Compounds
Rolling Knolls Landfill, Chatham, New Jersey

Chemical Form	Test Organism	Study Duration	Exposure Route	Dosage	Endpoints	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	Ing rate (Kg/day)	Body Wt (Kg)	TRV_{NOAEL} (mg/kg-day)	TRV_{LOAEL} (mg/kg-day)	Same TRV used in Work Plan?	Source/Comments
Endrin	Ring-necked pheasant	120 days	Oral in diet	Three doses in diet: 0.5, 1, 2, and 10 mg/kg	Survival	NOAEL, LOAEL	2 mg/kg in diet	10 mg/kg in diet	0.0582	1	1.16E-01	5.82E-01		DeWitt (1956). Converted to TRVs by using calculated ingestion rate (Nagy, 1987) and assumed body weight (Sample et al. 1996).
					Reproduction	NOAEL, LOAEL	1 mg/kg in diet	2 mg/kg in diet	0.0582	1	5.82E-02	1.16E-01		
Endrin	Screech Owl	83 days	Oral in diet	Single dose; 0.75 mg/kg in food	Reproduction	LOAEL	---	0.75 mg/kg in food	0.025	0.181	1.04E-02	1.04E-01	Yes	$TRVL_{OAEL}$ value was derived by Sample et al (1996) based on study by Fleming et al. (1982). Measurement endpoint was reproduction. The TRV_{NOAEL} value was assumed to one-tenth this value by Sample et al (1996).
Endrin	Mallard Duck	44 days	Oral in diet	Control and two test doses: 0.5 and 3 mg/kg.	Reproduction	NOAEL, LOAEL	0.5 mg/kg in diet	3 mg/kg n idet	0.125	1.25	5.00E-02	3.00E-01		Roylance et al (1985). Converted to TRVs by using calculated ingestion rate (Nagy, 1987) and average of male and female body weights estimated from figures in original paper.
Endrin	Duck	227 days	Oral in diet	Control and two test doses: 1 and 3 mg/kg.	Survival	NOAEL	3 mg/kg in diet	---	0.115	1.15	3.00E-01	---		Spann et al (1996). Sample et al (1996) converted to TRV_{NOAEL} using assumed body weight an dingestion rate.
					Reproduction	NOAEL	3 mg/kg in diet	---	0.115	1.15	3.00E-01	---		

		TRV_{NOAEL}	TRV_{LOAEL}
Species other than Ducks	*Min*	1.04E-02	1.04E-01
	Max	1.16E-01	5.82E-01
	Average	6.17E-02	2.67E-01
	Geomean	4.12E-02	1.91E-01
	N	3	3
Ducks	*Min*	5.00E-02	3.00E-01
	Max	3.00E-01	3.00E-01
	Average	2.17E-01	3.00E-01
	Geomean	1.65E-01	3.00E-01
	N	3	1

ED_004977_00066526-00113

Table 3-3. Data Sources Used to Develop Avian Toxicity Reference Values for PCBs
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	TRV_{NOAEL} (mg/kg-day)	TRV_{LOAEL} (mg/kg-day)	Include for TRV calculation?	Source/Comments
Aroclor 1254	Ringed turtle dove	6 months (180 days)	Reproduction	Oral in diet	10 ppm in diet	NOAEL	10 ppm	---	1.10E+00	---	Yes	Peakall (1971)
Aroclor 1254	Ring-necked pheasant	17 wks (119 days)	Reproduction	Oral by gelatin capsule	Two dose levels: 12.5 and 50 mg/bird/week.	NOAEL, LOAEL	12.5 mg/wk	50 mg/wk	1.80E+00	7.10E+00	Yes	Dahlgren et al. (1972)
Aroclor 1254	Northern bobwhite	2 yrs (730 days)	Reproduction	Oral in diet	50 ppm in diet	NOAEL	50 ppm	---	4.70E+00		Yes	Heath et al. (1972)
Aroclor 1254	Mallard duck	2 yrs (730 days)	Reproduction	Oral in diet	25 ppm in diet	NOAEL, LOAEL	25 ppm in diet	50 ppm	7.00E+00	1.40E+01	Yes	Heath et al. (1972)
Aroclor 1254	Chickens	39 wks (273 days)	Reproduction	Oral in diet	Two dose levels: 5 and 50 ppm in diet	LOAEL	---	5 ppm	---	3.50E-01	Yes	Platonow and Reinhart (1973)
Aroclor 1254	Ringed turtle dove	NR	Reproduction	Oral in diet	10 ppm in diet	LOAEL	---	10 ppm	---	1.10E+00	Yes	Peakall and Peakall (1973). Data was from F1 generation of Peakall (1971) study.
Aroclor 1254	Chickens	9 wks (63 days)	Reproduction	Oral in diet	Two dose levels: 2 and 20 ppm in diet	NOAEL, LOAEL	2 ppm	20 ppm	1.41E-01	1.41E+00	Yes	Cecil et al (1974).
Aroclor 1254	Chickens	9 wks (63 days)	Reproduction	Oral in diet	Two dose levels: 2 and 20 ppm in diet	NOAEL, LOAEL	2 ppm	20 ppm	1.24E-01	1.24E+00	Yes	Lillie et al (1974)
Aroclor 1254	Chickens	8 wks (56 days)	Reproduction	Oral in diet	Three dose levels: 5, 10 and 20 ppm in diet	NOAEL, LOAEL	20 ppm	---	1.24E+00	---	Yes	Lillie et al (1975). The authors evaluated other Aroclor PCB mixtures as well. Values shown here are for Aroclor 1254 only.
Aroclor 1254	Duck	4 mos (120 days)	Reproduction	Oral in diet	40 ppm in diet	NOAEL	40 ppm	---	4.00E+00	---	Yes	Riseborough and Anderson (1975)
Delor 105 (54% by weight chlorine)	Chickens	6 wks (42 days)	Reproduction	Oral in diet	5 ppm	NOAEL	5 ppm	---	3.53E-01	---	Yes	Kosutsky et al (1979)
Aroclor 1254	Ring-necked pheasant	NR	Reproduction	Oral in diet	50 ppm in diet	LOAEL	---	50 ppm	---	2.90E+00	Yes	Roberts et al. (1978); as reported in EPA (2000).
Aroclor 1254	Duck	1 month (30 days)	Reproduction	Oral in diet		NOAEL	25 ppm in diet	---	7.00E+00	---	No	Custer and Heinz (1980)
Environmental PCBs	Chickens	10 wks (70 days)	Growth, Reproduction	Oral in diet	0.3, 0.8, and 6.6 ppm in diet	NOAEL	0.8 ppm	---	4.58E-02	---	Yes	Summer et al (1996). TRV calculated using average body weight and feed consumption rate of intermediate dose group.
Environmental PCBs	Tree swallows	Field	Reproduction	Oral in diet	Up to 0.61 mg/kg in diet	NOAEL	0.61 ppm	---	5.50E-01	---	Yes	Custer et al. (1998). Populations in Fox River and Green Bay, Michigan. DDE also reported in samples. TRV shown is value reported by EPA (2000).

Group	Statistic	TRV_{NOAEL} (mg/kg-day)	TRV_{LOAEL} (mg/kg-day)
All Birds other than Duck; All Values	*Min*	0.046	0.350
	Max	4.700	7.100
	Average	1.118	2.351
	Geomean	0.496	1.551
	N	9	6
All Birds other than Duck; Bounded Values	*Min*	0.124	1.243
	Max	1.800	7.100
	Average	0.689	3.252
	Geomean	0.316	2.319
	N	3	3
Duck; All Values	*Min*	4.000	14.000
	Max	7.000	14.000
	Average	6.000	14.000
	Geomean	5.809	14.000
	N	3	1

Notes:
Only those studies with a minimum exposure period of 2 months were considered for the TRV derivation.
Study durations shown were as reported by the authors and were also adjusted to days to facilitate comparisons between studies.
There was a single bounded study using ducks.

Table 3-4. Data Sources Used to Develop Avian Toxicity Reference Values for Methyl Mercury
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Study Type	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage	Reported Toxicity Value(s)	Test Species NOAEL mg/kg	Test Species LOAEL mg/kg	TRV_{NOAEL} (mg/kg-day)	TRV_{LOAEL} (mg/kg-day)	Include for TRV calculation?	Source/Comments
Songbirds													
Methyl mercury	Field	Tree Swallow	Five breeding seasons	Repro	--	0.0438 mg/kg$_{dw}$ (mean, pre-flood)	NOAEL, LOAEL	0.0438	0.111	0.011	0.027	N	Gerrard and St. Louis (2001). Excluded because diet not directly measured.
Methyl mercury	Field	American Dipper	One breeding season	Repro	--	0.0212 - 0.112 mg/kg$_{dw}$ (range of site means)	NOAEL	0.112	--	0.020	--	N	Henny et al. (2005). Excluded because diet not directly measured.
Methyl mercury	Lab	Zebra Finch	76 days	Survival	Diet	<0.007 (control), 0.35, 0.88, 1.75 mg/kg$_{bw}$-day	NOAEL, LOAEL	0.88 mg/kg$_{bw}$-day	1.75 mg/kg$_{bw}$-day	0.880	1.750	N	Scheuhammer (1988). Excluded because no statistical evaluation of effects.
Methyl mercury	Lab	Zebra Finch	Two generations	Repro	Diet	0 (control), 0.35, 0.70, 1.39, 2.79 mg/kg$_{dw}$	LOAEL	--	0.35	--	0.097	Y	Varian-Ramos et al. (2014).
Wading birds													
Methyl mercury	Lab	White Ibis	Three years	Repro; Survival	Diet	0 (control), 0.05, 0.1, 0.3 mg/kg$_{ww}$	NOAEL	0.3	--	0.094	--	Y	Frederick and Jayasena (2011); Frederick et al. (2011)
Methyl mercury	Field	Black-crowned night heron	Two breeding seasons	Growth	--	0.39 to 0.57 mg/kg$_{ww}$ (range of site means)	LOAEL	--	0.39		0.13	Y	Henny et al. (2002)
Methyl mercury	Field	Snowy Egret	Two breeding seasons	Growth	--	0.43 to 1.12 mg/kg$_{ww}$ (range of site means)	NOAEL	1.12	--	0.45		Y	Henny et al. (2002)
Methyl mercury	Lab/Field	Great Egret	Two breeding seasons (15 day dosing period)	Repro	Capsules administered to wild birds	0.35 (control), 1.32 mg/kg$_{bw}$-day	NOAEL	1.32 mg/kg$_{bw}$-day	--	1.320	--	N	Sepúlveda et al. (1999). Excluded because nestlings dosed during peak feather growth, which is a known mechanism of Hg sequestration in birds.
Methyl mercury	Lab	Great Egret	14 weeks	Growth	Diet	0.025 (control), 0.5, 5 mg/kg$_{ww}$	LOAEL	--	0.5	--	0.083	N	Spalding et al. (2000). Excluded because high levels of selenium in feed confound study results.
Other avian species													
Methyl mercury	Lab	American Kestrel	77-113 days	Repro	Diet	0 (control), 0.7, 2, 3.3, 4.6, 5.9 mg/kg$_{dw}$	LOAEL	--	0.7	--	0.12	Y	Albers et al. (2007)
Methyl mercury	Field	Common Loon	3-6 years	Repro	--	0.16 mg/kg$_{ww}$ (mean)	LOAEL	--	0.16	--	0.030	N	Burgess and Meyer (2008). Excluded because diet not directly measured.
Methyl mercury	Lab	Mallard Ducks	12 months	Repro	Diet	0 (control), 0.6, 3.4 mg/kg$_{dw}$	NOAEL, LOAEL	0.6	3.4	0.077	0.44	Y	Heinz (1974)
Methyl mercury	Lab	Mallard Ducks	2 years	Repro	Diet	0 (control), 0.5, 2.9 mg/kg$_{dw}$	NOAEL, LOAEL	0.5	2.9	0.064	0.37	Y	Heinz (1976)
Methyl mercury	Lab	Mallard Ducks	Three generations	Repro	Diet	0 (control), 0.48 mg/kg$_{dw}$	LOAEL	--	0.48	--	0.064	Y	Heinz (1979)

		TRV_{NOAEL}	TRV_{LOAEL}
All Species except duck; All Values	*Min*	0.064	0.064
	Max	0.451	0.435
	Average	0.171	0.202
	Geomean	0.120	0.157
	N	4	6
All Species except duck; Bounded Values	*Min*	---	---
	Max	---	---
	Average	---	---
	Geomean	---	---
	N	0	0
Duck; All Values	*Min*	0.064	0.064
	Max	0.077	0.435
	Average	0.070	0.290
	Geomean	0.070	0.218
	N	2	3
Duck; Bounded Values	*Min*	0.064	0.371
	Max	0.077	0.435
	Average	0.070	0.403
	Geomean	0.070	0.402
	N	2	2

Notes:
Only those studies with a minimum exposure period of 2 months were considered for the TRV derivation.

Table 4-1. Summary of Mercury or Methylmercury Toxicity Studies Used to Derive Tissue-Based TRVs for Fish
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Test Organism	Study Duration	Exposure Route	Dosage/Exposure	Measured Endpoints	Reported Toxicity Value(s)	Tissue Type	Test Species NOAEL (Tissue)	Test Species LOAEL (Tissue)	TRV_{NOAEL} (mg/kg$_{ww}$)	TRV_{LOAEL} (mg/kg$_{ww}$)	Included for TRV calculation?	Source/Comments
Methylmercury	Methylmercury chloride (diet)	Fathead minnow	~250 days	Diet	Control (0.006 mg/kg) or 2 dietary conc (0.87 and 3.93 mg/kg)	Survival	NOAEL	Carcass	3.7 mg/kg$_{ww}$	---	3.7	---	Y	Drevnick and Sandheinrich (2003) and Drevnick et al. (2006). Reproductive endpoint excluded because of poor performance of controls.
						Growth	NOAEL		3.7 mg/kg$_{ww}$	---	3.7	---	Y	
						Reproduction	LOAEL		---	0.891 mg/kg$_{ww}$	---	0.891	N	
Methylmercury	Methylmercury chloride (diet)	Fathead minnow	30 days	Diet	Control (0.02 mg/kg) or 2 dietary conc (0.87 and 5.5 mg/kg)	Reproduction	NOAEL, LOAEL	Muscle	0.6 mg/kg$_{ww}$	3.21 mg/kg$_{ww}$	0.6	3.21	Y	Bridges et al. (2016)
Methylmercury	Methylmercury chloride (diet)	Zebrafish	30 days	Diet	Control (0.05 mg/kg) or 1 dietary conc (12 mg/kg)	Survival	LOAEL	Whole body	--	6.66 mg/kg$_{ww}$	--	6.66	Y	Penglase et al. (2015)
						Growth	LOAEL	Whole body	--	6.66 mg/kg$_{ww}$	--	6.66		
						Reproduction	LOAEL	Whole body	--	6.66 mg/kg$_{ww}$	--	6.66		
Methylmercury	Methylmercury chloride	Medaka	210 days	Aqueous	Control (0 ng/L) or 3 aqueous conc (0.01, 0.1 and 1 ng/L)	Survival	LOAEL	Whole body	--	0.048 mg/kg$_{ww}$	--	0.048	Y	Liao et al. (2007)
Methylmercury	Methylmercury chloride (diet)	Fathead minnow	~380 days	Diet	Control (0.006 mg/kg) or 3 dietary conc: (0.88 (low), 4.11 (medium), and 8.46 mg/kg$_{dw}$ (high)	Survival	NOAEL	Carcass	5.68 mg/kg$_{ww}$		5.68		Y	Hammerschmidt et al. (2002)
						Growth	NOAEL		5.68 mg/kg$_{ww}$		5.68			
						Reproduction	LOAEL		---	0.778 mg/kg$_{ww}$	---	0.778		
Methylmercury	Methylmercury chloride (diet)	Rainbow Trout		Diet	Control (<0.1 mg/kg) or 3 dietary conc (23.9, 46.9 and 94.8 mg/kg)	Growth	LOAEL	Whole body	---	10 mg/kg$_{ww}$	---	10	Y	Rodgers and Beamish (1982)
Methylmercury	Methylmercury chloride (diet)	Fathead minnow		Diet	Control (0.006 mg/kg) or 2 dietary conc (0.87 and 3.93 mg/kg)	Reproduction	LOAEL	Carcass	---	0.143 mg/kg$_{ww}$	---	0.143	Y	Sandheinrich and Miller (2006). Reproductive endpoint excluded because of poor performance of controls.
Mercury (total)	Mercury (sediment exposure)	Mosquitofish	NR	Mesocosm-Sediment	Control plus mesocosm sediment (Hg conc not reported)	Growth	NOAEL	Whole body	5.86 mg/kg$_{ww}$	---	5.86	---	Y	Tatara et al. (2002)
						Reproduction	LOAEL	Whole body	---	5.86 mg/kg$_{ww}$	---	5.86		
Methylmercury	Methylmercury chloride (diet)	Golden shiner		Diet	Control (0.012 mg/kg) or 2 dietary conc (0.455 and 0.959 mg/kg)	Growth	NOAEL	Whole body	0.518 mg/kg$_{ww}$	---	0.518	---	Y	Webber and Haines (2003)
						Survival	NOAEL	Whole body	0.518 mg/kg$_{ww}$	---	0.518	---		
Methylmercury	Methylmercury chloride (diet)	Sheepshead minnow	70 days	Diet	Control (0.04 mg/kg) or 3 dietary conc (1.04, 5.02, or 9.9 mg/kg)	Reproduction	NOAEL, LOAEL	Carcass	4.6 mg/kg$_{ww}$	7.6 mg/kg$_{ww}$	4.6	7.6	Y	Stefansson et al. (2014)
Methylmercury	Methylmercury chloride (diet)	Inland Silveride	70 days	Diet	Control or four dietary conc (0.56, 3.33, 6.78 and 13.96 mg/kg)	Survival	NOAEL, LOAEL	Whole body	7 mg/kg$_{ww}$	31 mg/kg$_{ww}$	7	31	Y	Stefansson et al. (2013)
						Growth	NOAEL, LOAEL	Whole body	10 mg/kg$_{ww}$	31 mg/kg$_{ww}$	10	31		
Mercury (inorganic)	Mercury chloride	Fathead minnow	41 weeks	Aqueous	Control water or one of five water conc (0.26, 0.5, 1.02, 2.01, and 3.69 µg/L)	Survival	NOAEL	Whole body	18.8 mg/kg$_{ww}$		18.8	---	Y	Snarksi and Olsen (1982)
						Growth	LOAEL	Whole body		1.36 mg/kg$_{ww}$	---	1.36		
						Reproduction	NOAEL, LOAEL	Whole body	1.36 mg/kg$_{ww}$	4.47 mg/kg$_{ww}$	1.36	4.47		
Methylmercury	Methyl mercuric chloride	Brook Trout	3 generations (144 weeks)	Aqueous	Control water or one of four water conc (0.03, 0.29, 0.93, 2.93 µg/L)	Survival (F0)	NOAEL, LOAEL	Whole body	9.4 mg/kg$_{ww}$	23.5 mg/kg$_{ww}$	9.4	23.5	Y	McKim et al. (1976)
						Reproduction (F0)	NOAEL, LOAEL	Whole body	3.4 mg/kg$_{ww}$	9.4 mg/kg$_{ww}$	3.4	9.4		
						Growth (F0)	NOAEL, LOAEL	Whole body	3.4 mg/kg$_{ww}$	9.4 mg/kg$_{ww}$	3.4	9.4		
						Survival (F1)	NOAEL, LOAEL	Whole body	2.0 mg/kg$_{ww}$	9.5 mg/kg$_{ww}$	2	9.5		
						Reproduction (F1)	NOAEL, LOAEL	Whole body	2.0 mg/kg$_{ww}$	9.5 mg/kg$_{ww}$	2.0	9.5		

		TRV_{NOAEL}	TRV_{LOAEL}
All Data	*Min*	0.518	0.048
	Max	18.8	31.0
	Average	4.90	9.30
	Geomean	3.23	4.49
	N	18	19
Bounded Studies	*Min*	0.6	3.21
	Max	10	31.0
	Average	4.4	13.9
	Geomean	3.20	10.7
	N	10	10

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Table 4-2. Data Sources Used to Develop Fish Tissue-Based Toxicity Reference Values for Total PCBs
Rolling Knolls Landfill, Chatham, New Jersey

Chemical	Chemical Form	Test Organism	Study Duration	Endpoints	Exposure Route	Dosage/Exposure	Toxicity Value(s)	Test Species NOAEL	Test Species LOAEL	TRV_{NOAEL} (mg/kg)	TRV_{LOAEL} (mg/kg)	Value Used for ERA	Source Category	Source/Comments
Total PCBs	Aroclor-1254	Juvenile pinfish	24- or 48-hours (1 to 2 days)	Survival	Aqueous	Three water conc (1, 10 and 100 µg/L)	NOAEL	1.0 to 100 µg/L (0.98 to 17.0 mg/kg)	NR	17.0	---	No	ERED	Duke et al (1970). Study used estuarine species and was short-term, so it was not included in TRV derivation.
Total PCBs	Aroclor-1254	Juvenile spot	33 days	Survival	Aqueous	Control and 2 aqueous concentrations (1 and 5 mg/L)	NOAEL, LOAEL	27 mg/kg	150 mg/kg	27.0	150	Yes	Lit	Hansen et al. (1971)
Total PCBs	Clophen A50	Three-spined Sticklebacks	3.5 months (110 days)	Reproduction	Diet	Control, low, and high doses	LOAEL	--	102	--	102	Yes	Lit	Holm et al. (1993)
Total PCBs	Aroclor-1254	Sheephead Minnow	28 days	F1 Generation Survival	Aqueous	Five water conc (0.1, 0.32, 1.0, 3.2 and 10 µg/L) plus control	NOAEL, LOAEL	0.1 µg/L (1.9 mg/kg in adult)	0.32 µg/L (9.3 mg/kg in adult)	1.9	9.3	Yes	Lit	Hansen et al (1973); NOAEL and LOAEL were used for the Onondaga Lake BERA (NYSDEC, 2002) and Hudson River Revised BERA (EPA, 2000)
Total PCBs	Aroclor-1254	Juvenile Rainbow Trout	32 weeks (224 days)	Growth, Survival	Diet	Control and 15 mg/kg	NOAEL	8 mg/kg	NR	8.0	NR	Yes	ERED	Lieb et al (1974)
Total PCBs	Aroclor-1254	Juvenile Rainbow Trout	330 days	Growth, Survival	Diet	Control and 3 dietary conc (1, 10 and 100 mg/kg)	NOAEL	1.4 to 81.1 mg/kg	NR	81.1	NR	Yes	ERED	Nestel and Budd (1975)
Total PCBs	Aroclor-1254	Brook Trout Fry	10 days pre-hatch 118 days post-hatch	Growth, Survival	Aqueous	Multiple: 0.43 to 13 µg/L	NOAEL, LOAEL	31 mg/kg-growth	125 mg/kg-growth	31	125	Yes	ERED	Mauck et al (1978), as reported in USACE-ERED database.
								71 mg/kg-survival	125 mg/kg-survival	71	125			
Total PCBs	PCB-153	Chinook salmon fry	15 days	Survival	Aqueous	One water conc (5 µg/L)	LOAEL	--	5 µg/L (3.6 mg/kg)	---	3.6	No	Lit	Broyles and Noveck (1979). Not included in TRV derivation since exposure duration was short-term and looked at a single PCB congener.
Total PCBs	Clophen A50	Common Minnow	40 days exposed, monitor for additional 260 days	Growth, F1 Generation Survival	Diet	Control and 3 dietary conc (20, 200 and 2,000 mg/kg)	NOAEL, LOAEL	1.6 mg/kg	15 mg/kg	1.6	15	Yes	Lit	Bengtsson (1980)
Total PCBs	Aroclor-1254	Lake trout Larvae	NR	Growth, Survival	NR	NR	NOAEL, LOAEL	NR	NR	26	1.53	Yes	ERED	Berlin et al (1981), as reported in USACE-ERED database. NOAEL based on growth, LOAEL based on survival.
Total PCBs	Aroclor-1254	Lake Trout Fry	48 days	Growth, Survival	Diet and aqueous	Control, 50 ng/L in water, diet was 0.72 mg/kg	NOAEL	5.0 to 7.3 mg/kg	NR	7.3	NR	Yes	ERED	Mac and Seelye (1981)
Total PCBs	Aroclor-1254	Juvenile Chinook Salmon	28 days	Growth	Diet	Control and 4 dietary conc (0.43, 1.1, 2.8 and 17 mg/kg)	NOAEL	0.044 to 0.95 mg/kg	NR	0.95	NR	Yes	ERED	Powell et al (2003); reported in USACE-ERED database.
Total PCBs	Multiple	Juvenile salmonids (smolts)	Varied	Biomarkers, diseases, growth and reproduction	Diet and aqueous	NA	NOED	2.4 µg/glipid (0.048 mg/Kg)	9.30E+00	2.4 µg/glipid (0.048 mg/Kg)	NR	No	Lit	Meador et al (2002), reviewed 15 studies and developd a lipid-based NOAEL. Wet weight value based on 2% lipid content. This reference was evaluated in the Housatonic River ERA but was not included in their TRV derivation (EPA, 2003).

		TRV_{NOAEL} (mg/kg)	TRV_{LOAEL} (mg/kg)
All Studies	*Range*	0.95 - 81.1	1.53 - 125
	Average	25.6	75.4
	Geometric Mean	10.8	33.9
Bounded Only	*Range*	1.6 - 71	1.53 - 150
	Average	22.7	71.0
	Geometric Mean	13.0	28.2

Note:
TRV values are on a whole body wet weight basis.
When multiple NOAEL or LOAEL values are reported based on the same endpoint, the highest reported value was used for the TRV calculations.
NR = not reported or not required
Study durations shown were as reported by the authors and were also adjusted to days to facilitate comparisons between studies.